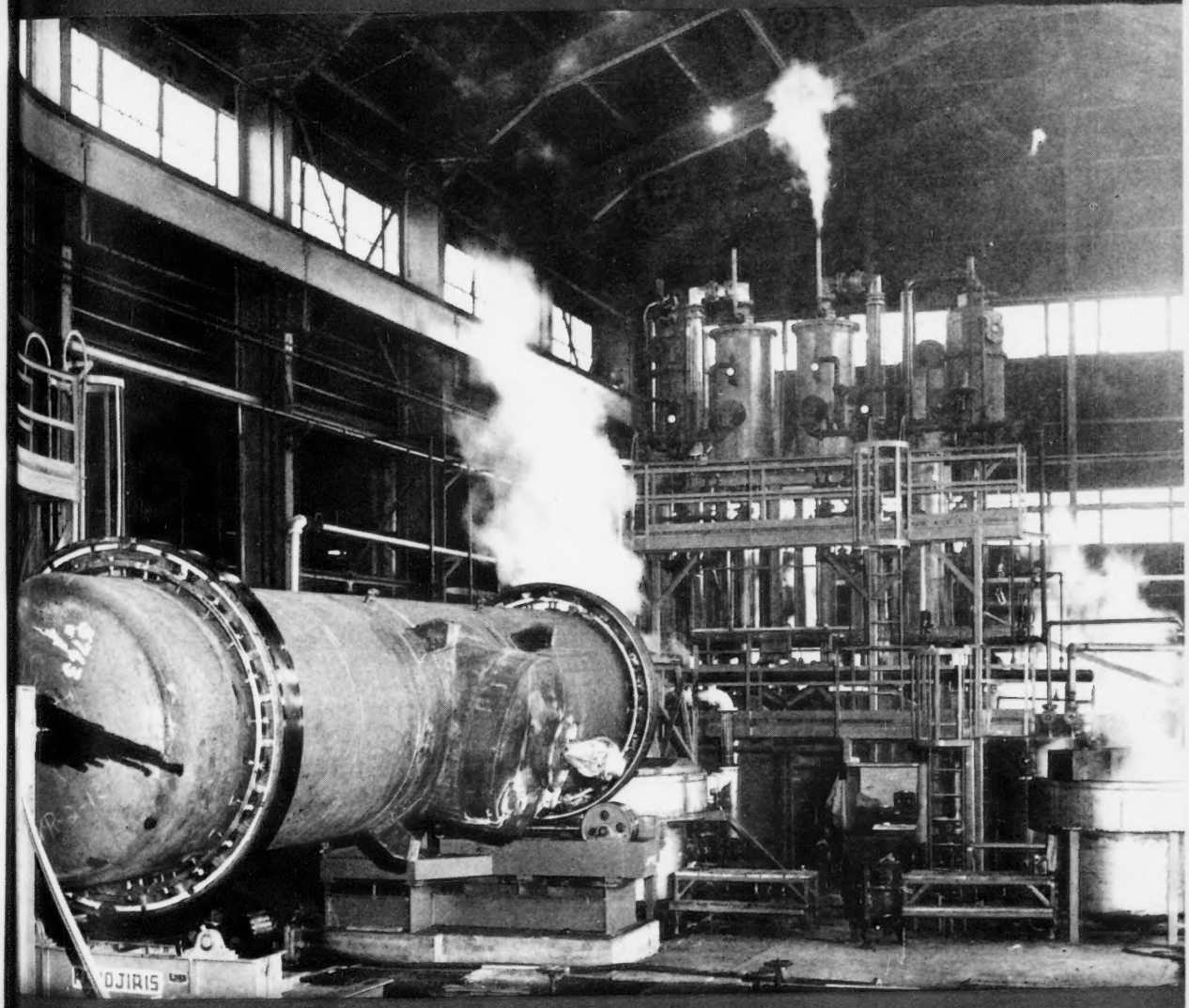
Corrosion

Official Publication

NATIONAL ASSOCIATION OF CORROSION ENGINEERS



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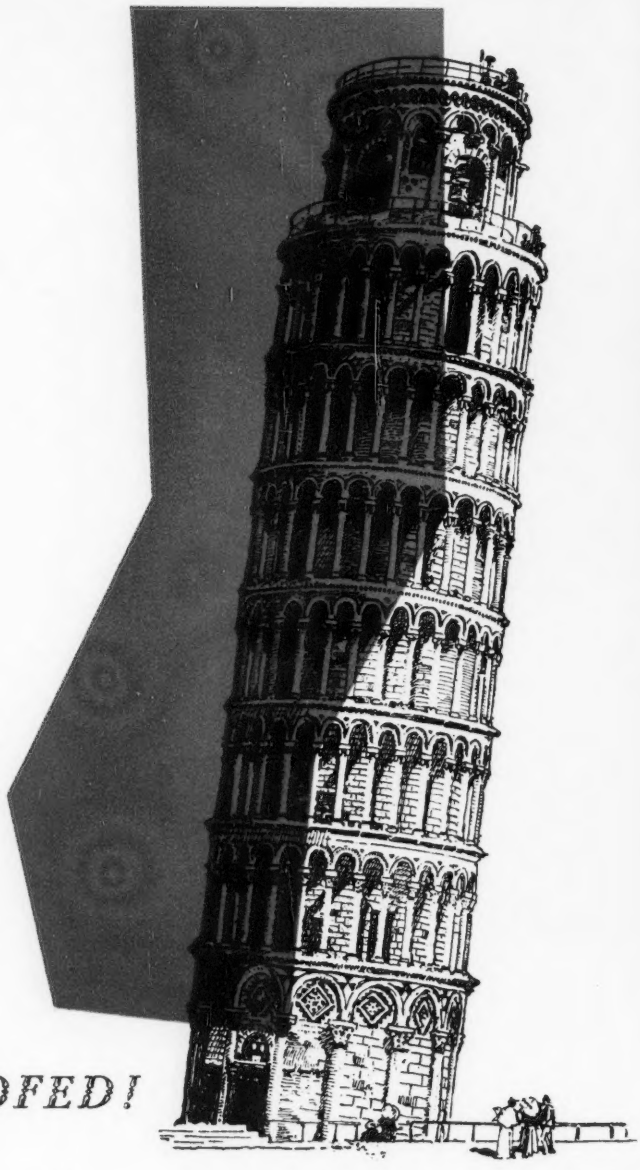

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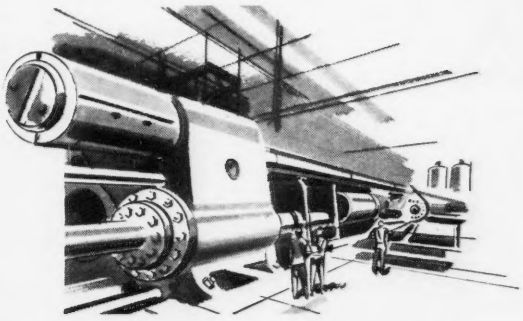

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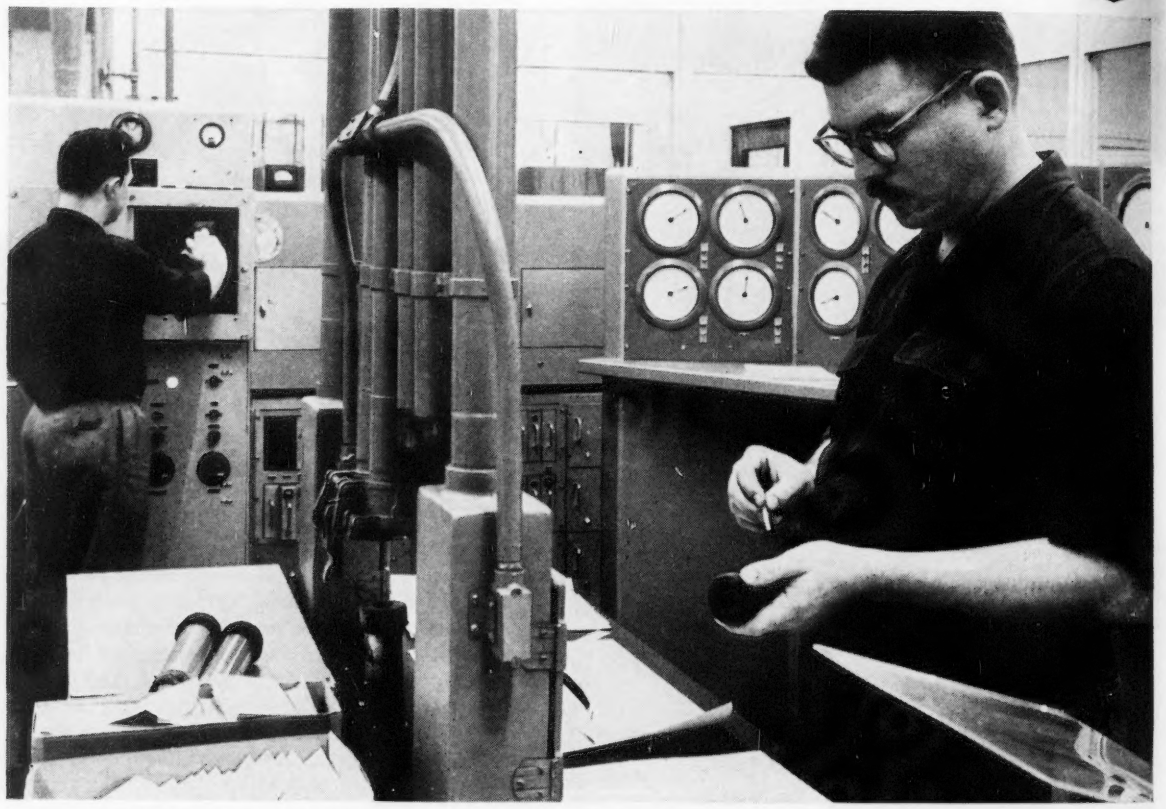

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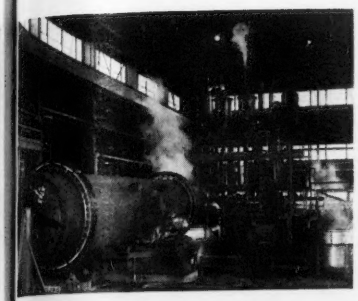

THIS MONTH'S COVER—An 8000-gallon railroad tank car is shown here being lined with nickel alloy by the General American Transportation Corporation's chemical coating process "Kanigen." Tank rotates while plating solution circulates from the solution heating and cooling systems. This operation is under way at the Sharon, Pennsylvania installation of GATX.

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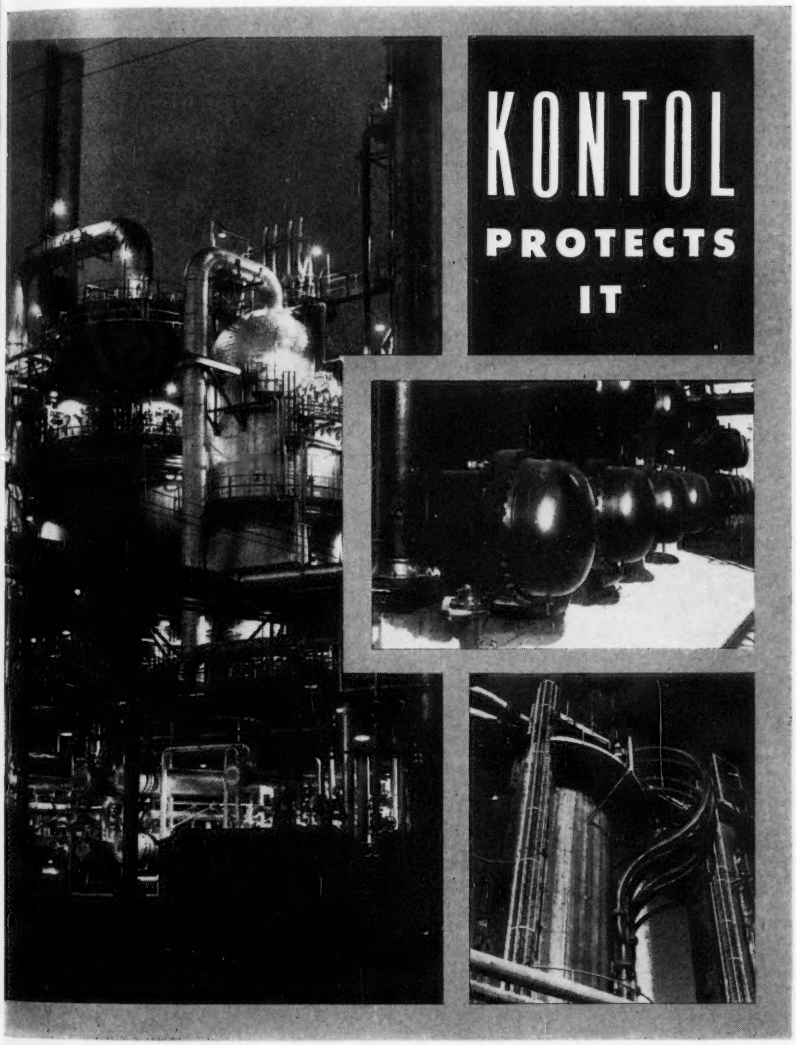

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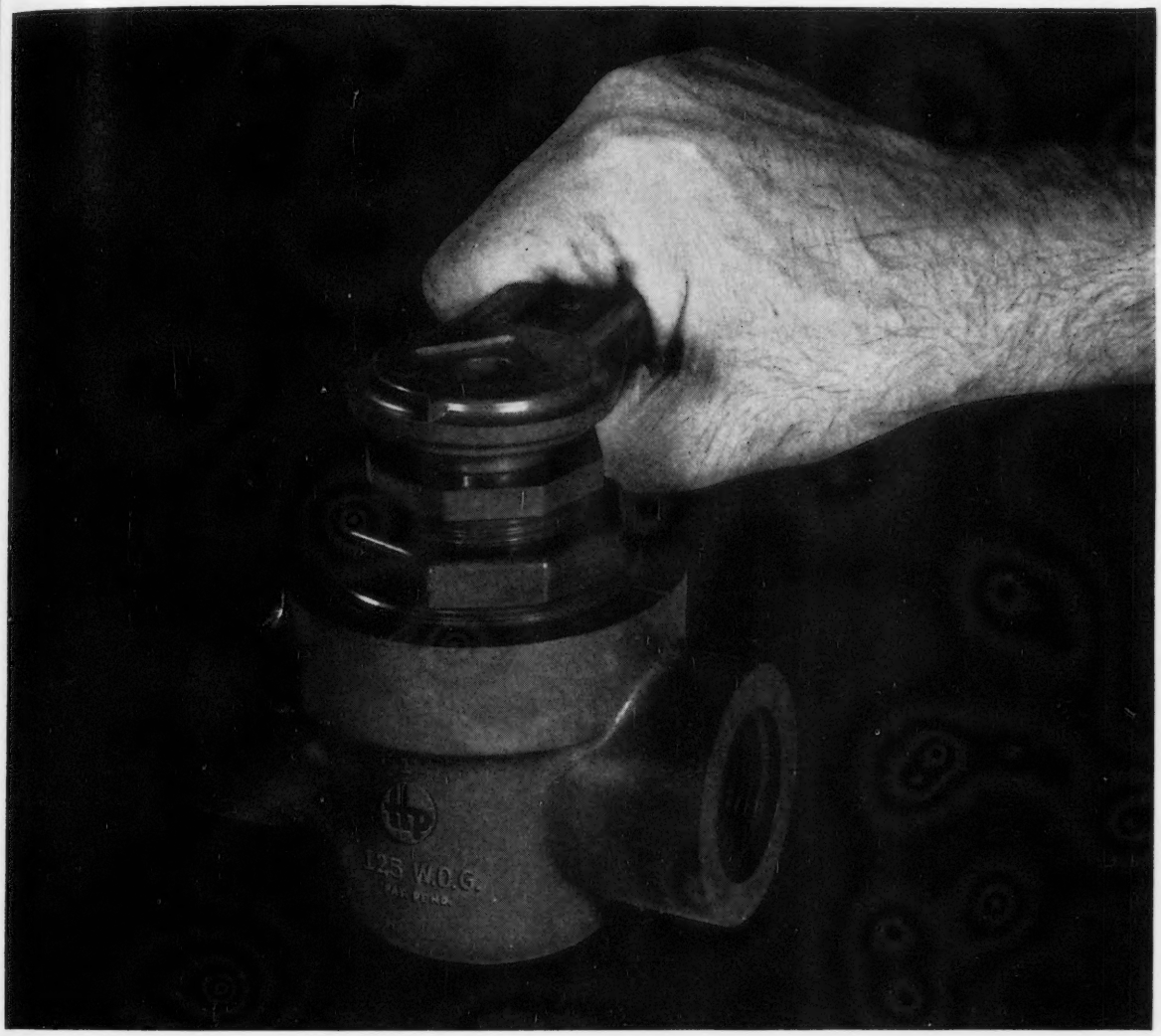
(Continued on Page 8)



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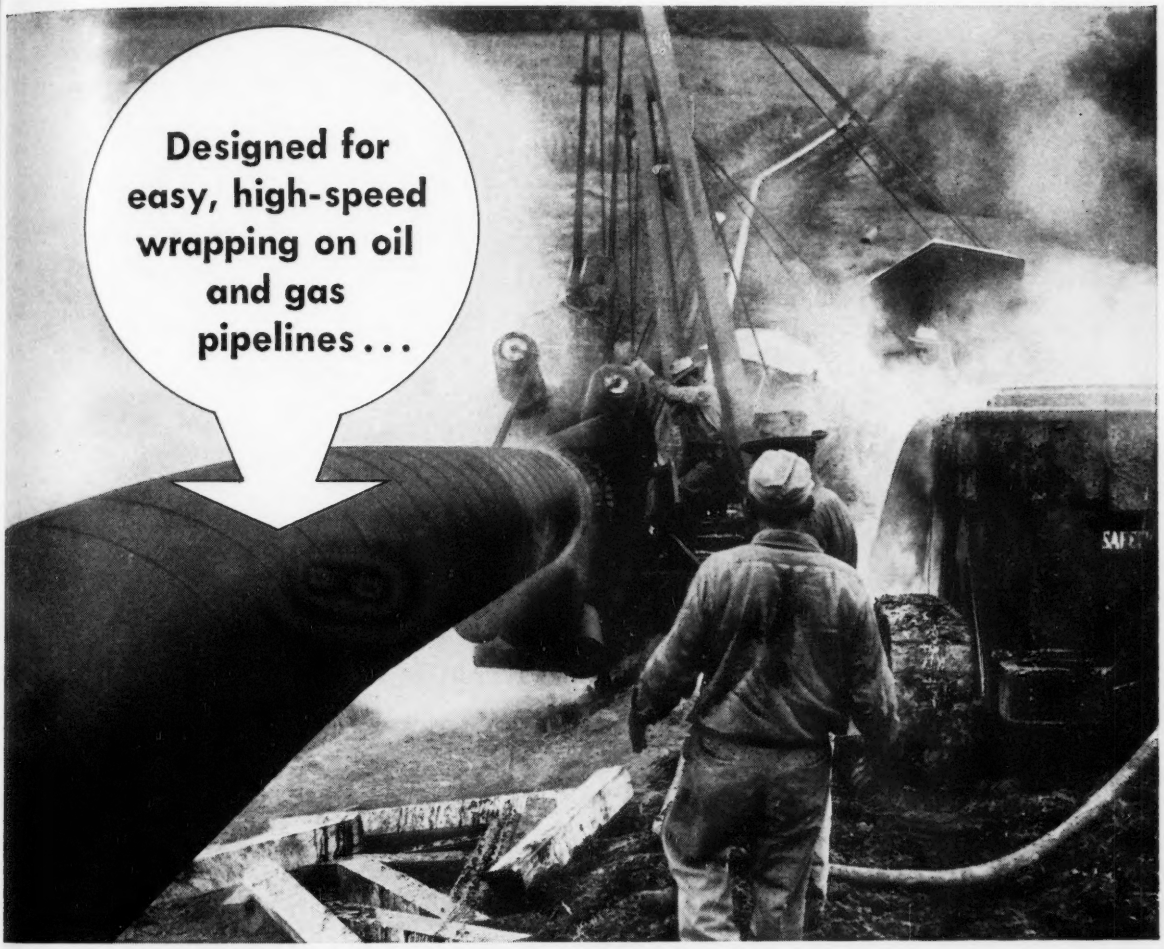

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Oxidation

...and its effect on metals at high temperature

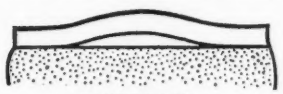
High-temperature corrosion is one of the basic processes by which metals fail, and oxidation is truly a process of high-temperature corrosion.

The formation of an oxide film is accompanied by a change in volume that puts the film under compressive stress. Subsequently, when the underlying metal cools, it contracts, further aggravating the stress situation. Eventually, under repetitive heating and cooling cycles the normally protective oxide may rupture from the metal surface.

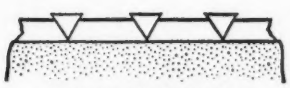
Obviously, such ruptures result in progressive loss of useful load-carrying metal by oxidation.

Resistance to oxidation, therefore, is notably affected by the behavior of the oxide scale. It may be a tightly adherent protective scale, or it may break down in one of the ways shown in the sketches, and thus accelerate oxidation.

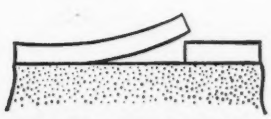
Oxide Scale Breakdown by:



BLISTERING



SHEAR CRACKING



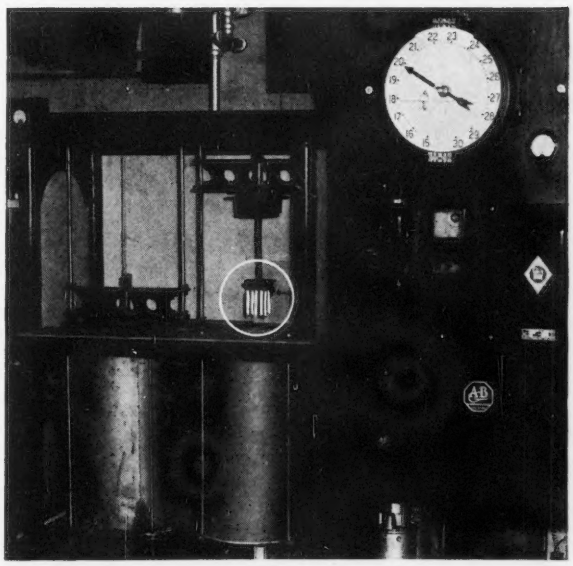
FLAKING OR SPALLING

Blistering may occur in oxide layers having good elasticity but poor adherence to the metal surface.

Shear cracking on the other hand will be found in oxides that are adherent but relatively brittle.

Flaking or spalling results when the oxide is both brittle and non-adherent.

When scale peels away, fresh areas of metal are exposed to attack. Accordingly, the economy of alloys that provide tight, adherent scale is self-evident.



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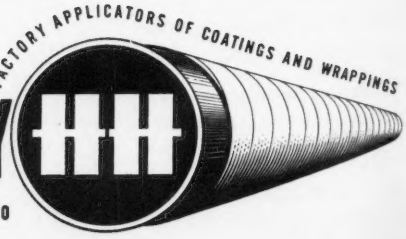

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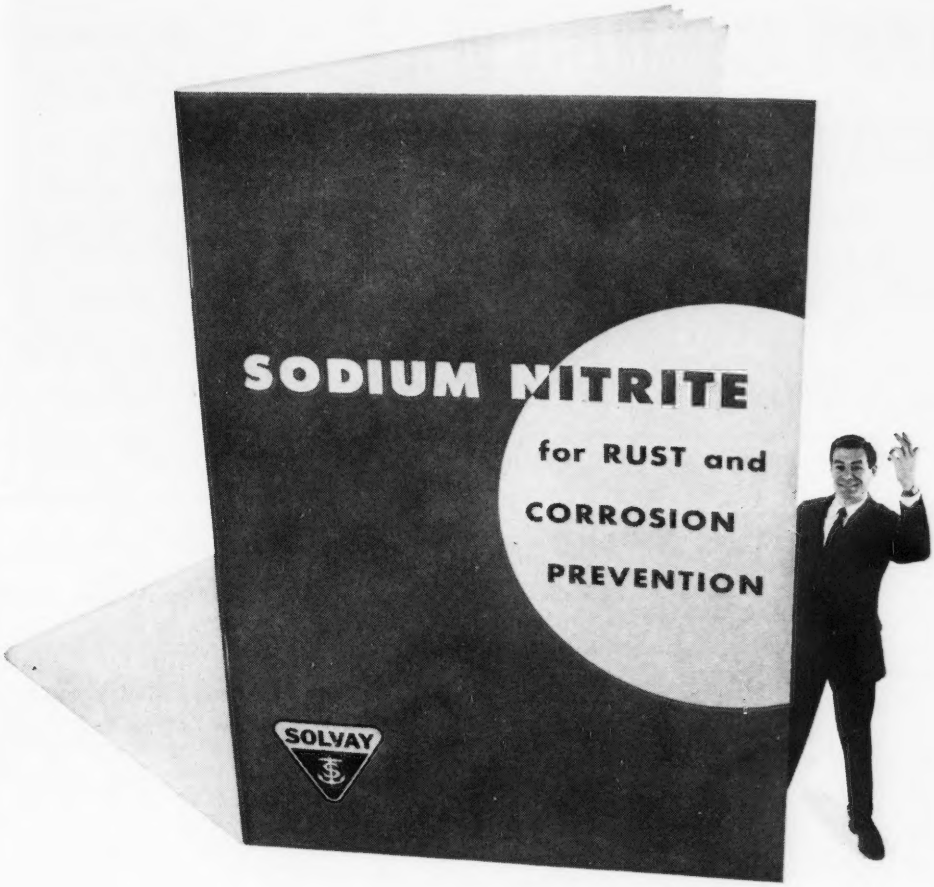

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(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of memberships, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

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Topic of the Month

Stray Current Drainage Switch For Gas Distribution System

By E. C. PAVER*

THE INJURIOUS effect of stray railway current has been a problem to utilities for many years, particularly to the gas distribution systems having electric railways crossing through or bordering their territory. The necessity for proper control of these vagabond currents is very important. This is particularly true at locations where the underground structure becomes positive to the DC negative. The complexities of a gas distribution system in a stray current area are multifold, as the system is usually crosstied to the water system as well as having stub ends, high resistant joints, and other grounds. The piping often is of diverse ages, sizes, and coating conditions which add to the problem.

Up until a few years back, there were only a few devices that were available for installation for proper control of stray currents. Such instruments were not reliable as maintenance and constant inspection were expensive. The older switches did a reasonably good job, but an improved model has made the problem of stray current control much more economical and practical.

A reverse current switch, in minimizing and controlling stray current, should perform as an automatic valve in a metallic tie between the gas system and the ground or negative of the railway, allowing current to flow off the gas mains without harm to the supplying system.

The switch as illustrated by the wiring diagram (Figure 1) and photograph (Figure 2) has proven to be very capable of handling stray current drainage under most varied conditions. It has speed of operation, and by proper selection of components, the maintenance and constant adjustment is minimized.

The heart of the switch is the polarized relay which has fine adjustment for closing and opening the remainder of the circuit for the control needed according to conditions present. The polarized relay, energized through the circuit by potential between the gas system and the DC negative, on closing energizes an intermediate relay coil. This relay coil energizes the magnetic switch or main contactor coil closing the contact for completing the tie for drainage. Reverse potential opens all contacts in sequence.

Protection against overvoltage and high current to the polarized relay is provided by ballast lamps and a rectifier plate in the circuit. The elimination of chattering from induced alternating current is provided by the retardation or choke coil. The main contactor should be provided with a magnetic blowout coil and interlock in the control circuit. The interlock must be adjusted to open slightly ahead of the main contactor to prevent damage to the polar-

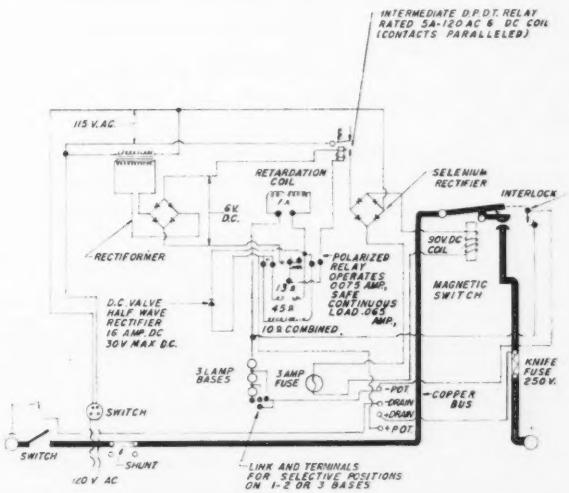

Figure 1—Wiring diagram of reverse current switch.

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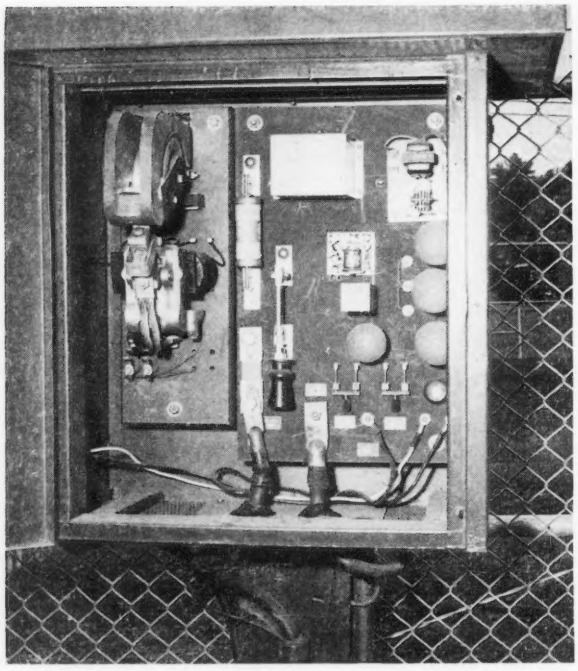

Figure 2—Closeup view of reverse current switch.

ized relay. Allowances for wear should be maintained.

The inclusion of fuses, shunts for current measurement, and switches in the DC circuit and the AC circuit also is necessary and may be rated to suit prevailing conditions. It might be added that this switch may be assembled from easily obtained components; also that the quality of current equipment eliminates a great deal of maintenance.

This switch, unlike others, depends entirely on 115 volt AC service. This does not create any serious problems, however, because such current usually is available and dependable in locations where switches are required.

The switch described in this paper is in use for stray current control by the Northern Illinois Gas Company which has three electric railroads and two Chicago Transit Authority lines through its territory with a track mileage of more than 100 miles. The majority of the installations are in the suburban towns and are usually installed where direct ties to substation negatives are available. Ten of these switches are in service and the operation and maintenance are very good. The switches were assembled by the members of the Corrosion Department. Maintenance, repairs, and adjustments have been at a minimum since installation (for some switches the time since installation amounts to five years).

A good feature about the assembly is that the control circuit is standard for any size main contactor. The above mentioned switches range in capacity from 150 amperes to 450 amperes. This type of switch has become a standard on many new installations in the Chicago and suburban areas.

Calculation of the pH of Oil Well Waters*

By WALTER F. ROGERS

Introduction

ACIDIC AQUEOUS conditions are well known as conducive to high corrosion rates of ferrous materials. In studying the causes of corrosion of oil and gas well equipment, however, the effect of acidity has not been fully investigated. To date it is well known that waters produced by condensate wells are usually acid in character, and it is a reasonably well established fact that severe corrosion takes place when the well fluid contains sufficient dissolved carbon dioxide and/or lower aliphatic acids to maintain such acid pH.[1]

The relation of pH to corrosion in oil wells producing brines is somewhat less clear. This is particularly due to the fact that, whereas the pH of oil well brines may be acid under bottom hole conditions,[2] they are usually neutral-to-alkaline at the top of the hole (i.e., pH 6.7 to 8.5). Rogers and Rowe[3] have shown that pH is of greater importance in promoting corrosion in wells producing non-sulfide brines than in wells producing sulfide-bearing fluids.

In order to prove whether acid waters are important causes of oil well subsurface corrosion it is necessary to develop a means of calculating the pH at any desired point in the well stream. It is the purpose of this study to present such a method. Because of the lack of precise constants the method presented is not to be taken as exact. It is believed, however, to give close approximation.

Cases Considered

The chemical composition of waters from crude oil and condensate wells varies to the extent that three differences in technique are required to calculate the down hole pH values. In the discussions which follow only waters free of hydrogen sulfide are considered, although the same methods would be used in the presence of this compound. Waters may be grouped as follows:

1. **Oil well brines of well head pH 6.7 to 8.5.** The majority of oil well brines are free of mineral acids or strong bases, and the pH is controlled by the amounts of carbon dioxide and bicarbonate in the water. This report is concerned principally with the development of a method of calculating the down hole pH values of waters of this type.

2. **Oil well brines of well head pH less than 6.7.** A small number of brines are produced with an acid pH under atmospheric conditions. If the pH is 6.7 or less the concentration of non-volatile residual acid must be added to the dissolved carbon dioxide to obtain the pH within the well.

3. **Condensate waters.** These waters are low in dissolved salts and contain non-volatile acids of the lower aliphatic type. The pH is frequently increased during production by reaction with the metal tubing. The acidity of these waters must be adjusted for the neutralization which takes place, in addition to adding the released carbon dioxide to determine the pH within the well.

Calculation of Dissolved Carbon Dioxide in Water Within Well

The foregoing discussion states, in effect, that the pH of a water can be calculated at any point in the well if (1) the dissolved carbon dioxide in the water is known, together with (2) the quantity of neutralizing salts, and (3) the quantity of non-volatile

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Abstract

Studies of the causes of corrosion of oil well tubular goods by the produced fluids require a knowledge of the pH of the well water at the point in the well where corrosion occurs. The well head pH of such water is not necessarily the pH of the water within the well because of the loss of acid gases, such as carbon dioxide, through pressure reduction on the fluid during the course of production. It is necessary, therefore, to recombine into the brine the amount of volatile acidic material to determine the pH at the point in question.

This study has developed a technique for calculating the down hole pH through such recombination. The technique covers three types of well waters: (1) Oil well brines, the pH of which is controlled by the carbonic acid-bicarbonate ratio, (2) Oil well brines containing top hole acidity as the result of hydrolysis of calcium and magnesium salts or organic acids, and (3) Condensate waters. **4.6.9**

* Submitted for publication April 23, 1956.

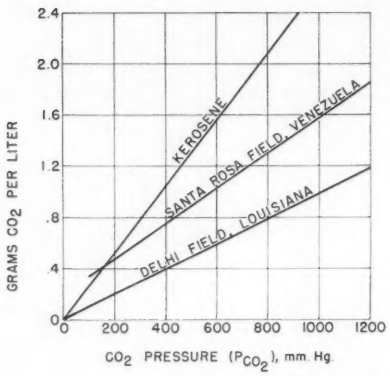

Figure 1—Typical solubility curves of CO_2 in kerosene and oil well brines at 100 F.

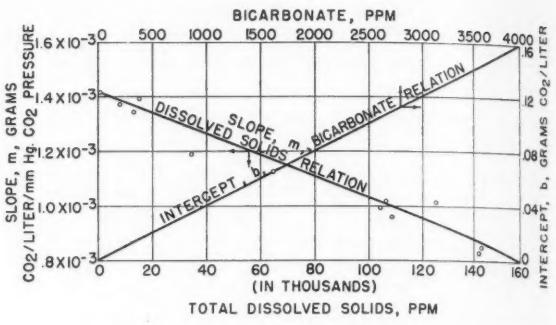

Figure 2—Chart for selecting values of m and b.

acids. Since the latter two items can be measured from a top hole water sample it remains only to calculate the dissolved carbon dioxide in the water in the well to be able to determine the pH at the point in question. The derivation of equations for calculating the dissolved carbon dioxide in the well water at any point follows.

The production from any well, oil, gas or condensate, consists of liquid hydrocarbons, gas and water. The total carbon dioxide produced is the sum of the amount in each of the three phases, or:

$$W_{co_2\text{-}T} = W_{co_2\text{-}w\text{-}T} + W_{co_2\text{-}o\text{-}T} + W_{co_2\text{-}g\text{-}T} \quad (1)$$

where: $W_{co_2\text{-}T}$ = Total weight of CO_2, grams
$W_{co_2\text{-}w\text{-}T}$ = Total weight of CO_2 in the water, grams
$W_{co_2\text{-}o\text{-}T}$ = Total weight of CO_2 in the oil, grams
$W_{co_2\text{-}g\text{-}T}$ = Total weight of CO_2 in the gas, grams

The method of calculating the carbon dioxide in each of the three phases (i.e., water, oil and gas) must be considered separately.

Calculation of Carbon Dioxide in Aqueous Phase.

Experimental determinations were made of the effect of partial pressure of carbon dioxide on the solution of this gas in a number of oil well brines at 100 F. A few typical results are shown in Figure 1. It was found that a straight line relation exists, allowing the amount of dissolved carbon dioxide to be calculated at any pressure by the relation:

$$W_{co_2\text{-}w/L} = P_{co_2} + b \quad (2)$$

where: $W_{co_2\text{-}w/L}$ = Weight of CO_2 in grams dissolved per liter of water
/ = Per (i.e., grams/liter = grams per liter)
m = Slope of the curve, grams CO_2/L/mm Hg pressure
P_{co_2} = Partial pressure of CO_2 in mm Hg
b = Intercept, grams CO_2/liter

The total weight of CO_2 produced by the water of a well in unit time becomes:

$$W_{co_2\text{-}w\text{-}T} = V_w (mP_{co_2} + b) \quad (3)$$

where: V_w = Liters of water produced

It was found in the studies that both the salt content of the water and the bicarbonate content had an influence on the amount of carbon dioxide absorbed. The salt content influences the slope, m, and the bicarbonate the intercept, b.

The effect of salt content on the value of slope, m, for waters of a wide range of salt content is given in Figure 2, together with values of m taken from other work. In addition, the effect of bicarbonate on the intercept, b, is shown. The value of slope, m, can be calculated by the relation:

$$m = 1.43 \times 10^{-3} - 0.40 \times 10^{-8}\ NaCl, ppm \quad (4)$$

The value of intercept is expressed by the relation:

$$b = 4 \times 10^{-5}\ HCO^-_3, ppm \quad (5)$$

The use of Equation (3) permits the weight of carbon dioxide in water at 100 F to be calculated for any value of carbon dioxide partial pressure.

Calculation of Carbon Dioxide in Oil Phase.

Figure 1 shows the experimental result of the effect of carbon dioxide pressure on solution in kerosene. This relation is linear as for water and is given by Formula (6). The slope of the curve was found at 100 F to be 2.62×10^{-3} gm CO_2/L/mm Hg. It will be noted that this is two to three times the solution of carbon dioxide in brine. The curve passes through the origin, so b = 0. In this study all oils and condensates are assumed to have the value of slope found for kerosene. The quantity of carbon dioxide adsorbed by oil then becomes:

$$W_{co_2\text{-}o/L} = 2.62 \times 10^{-3}\ P_{co_2} \quad (6)$$

where: $W_{co_2\text{-}o/L}$ = weight of CO_2 dissolved in the oil in grams/liter
P_{co_2} = partial pressure of CO_2 in mm Hg

The total weight of carbon dioxide produced in the oil from a well becomes:

$$W_{co_2\text{-}o\text{-}T} = V_o\ (2.62 \times 10^{-3}\ P_{co_2}) \quad (6\text{-A})$$

where: V_o = liters of oil produced.

If a knowledge of the total carbon dioxide in the oil at the well head, separator, or stock tank is desired, then the value of V_o is the liters of stock tank oil. If the carbon dioxide content of the oil within the well is desired, the value of V_o must be increased because of the effect of gas dissolved in the oil under

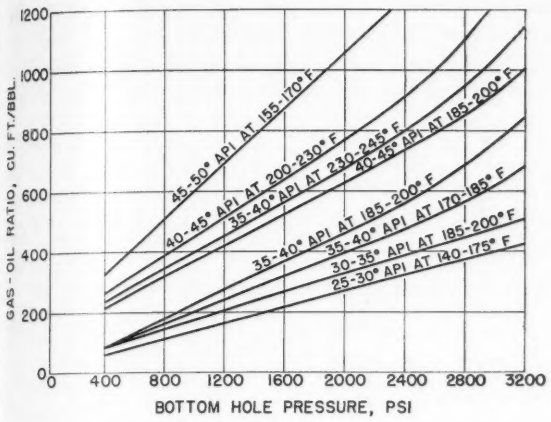
GAS - OIL RATIO, CU. FT./BBL.
BOTTOM HOLE PRESSURE, PSI
45-50° API AT 155-170° F
40-45° API AT 200-230° F
35-40° API AT 230-245° F
40-45° API AT 185-200° F
35-40° API AT 185-200° F
35-40° API AT 170-185° F
30-35° API AT 185-200° F
25-30° API AT 140-175° F

Figure 3—Relation of gas-oil ratio to bottom hole pressure.

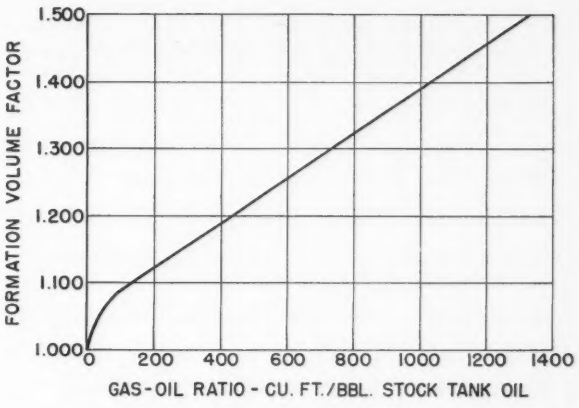

Figure 4—Relation of gas-oil ratio to formation volume factor of crude oil.

the well pressure. This desired increase is expressed by the factor f_x, the formation factor. This value is the ratio of the volume of one unit of stock tank oil in the well to its volume in the stock tank, or:

$$f_x = \frac{V\ (\text{well})}{V\ (\text{stock tank})} \qquad (7)$$

Estimation of the value of f_x is made through Figures 3 and 4. Figure 3 illustrates an approximate relation between pressure and dissolved gas in crudes of varying API gravities and at different temperatures. To use these curves it is necessary to select the depth in the well at which the pH is to be determined. The pressure gradient in the well is then measured or estimated and the product of depth and pressure gradient gives the pressure. From this knowledge of pressure and oil gravity the dissolved gas-oil ratio is read from Figure 3. The actual gas-oil ratio of the production must be measured. If this value is less than the gas-oil ratio taken from the curve then the actual gas-oil ratio is used. The actual gas-oil ratio or gas-oil ratio from Figure 3, whichever pertains, is then used with Figure 4 to determine the formation volume factor, f_x. This value used with Equation (6-B) gives the carbon dioxide dissolved in the oil at point X in the well:

$$W_{co_2\text{-}o\text{-}T} = V_o f_x\ (2.62 \times 10^{-3}\ P_{co_2}) \qquad (6\text{-B})$$

Calculation of Carbon Dioxide in Gas Phase.

Most wells produce gas in addition to oil and water. As the bottom of the well is approached the gas which was free at the top of the hole may become completely dissolved in the oil. As previously discussed in determining f_x, some of the free gas at the surface is dissolved in oil within the well. The volume of free gas at point x is desired and is calculated by Equation (8):

$$V_{G\text{-}x\text{-}T} = (V_{G\text{-}ats\text{-}T} - V_{G\text{-}sol\text{-}x\text{-}T})\frac{P_{ats}}{P_x} \qquad (8)$$

where: $V_{G\text{-}x\text{-}T}$ = Total volume of free gas at x in liters
$V_{G\text{-}ats\text{-}T}$ = Total volume of gas measured at the separator in liters, standard condition
$V_{G\text{-}sol\text{-}x\text{-}T}$ = Total volume of gas in solution at x in liters at standard condition
P_{ats} = Atmospheric pressure, mm Hg
P_x = Pressure at point x, mm Hg

Since the pressure at point x and the oil gravity are known from previous calculations, Figure 3 is again used to determine the gas in solution per barrel, which is converted to total liters to give the value of $V_{G\text{-}sol\text{-}x\text{-}T}$.

Knowing from Equation (8) the free gas at point x, the weight of CO_2 present is calculated:

$$W_{co_2\text{-}G\text{-}x} = (V_{G\text{-}ats\text{-}T} - V_{G\text{-}sol\text{-}x\text{-}T}) \times \frac{P_{ats}}{P_x} \times \frac{P_{co_2\text{-}x}}{P_x} \times \rho_{co_2\text{-}ats} \times \frac{P_x}{P_{ats}} \qquad (9)$$

which reduces to:

$$W_{co_2\text{-}G\text{-}x} = (V_{G\text{-}ats\text{-}T} - V_{G\text{-}sol\text{-}x\text{-}T})\frac{P_{co_2\text{-}x} \times \rho_{co_2\text{-}ats}}{P_x} \qquad (9\text{-A})$$

where: $\rho_{co_2\text{-}ats}$ = Density of CO_2 at atmospheric pressure in grams per liter

Calculation of Carbon Dioxide Pressure at Any Point in Well Stream.

The total weight of CO_2 produced can now be calculated according to Equation (1) by adding Equations (3), (6-B) and (9-A):

$$W_{co_2\text{-}T} = V_w\ (mP_{co_2} + b) + V_o f_x\ (2.62 \times 10^{-3}\ P_{co_2}) + (V_{G\text{-}ats\text{-}T} - V_{G\text{-}sol\text{-}x\text{-}T})\ \frac{P_{co_2\text{-}x}\ \rho_{co_2\text{-}ats}}{P_x} \qquad (10)$$

Equation (10) is now solved for $P_{co_2\text{-}x}$:

$$P_{co_2\text{-}x} = \frac{W_{co_2\text{-}T} - V_w b}{V_w m + 2.62 \times 10^{-3} f_x V_o + (V_{G\text{-}ats\text{-}T} - V_{G\text{-}sol\text{-}x\text{-}T})\frac{\rho_{co_2\text{-}ats}}{P_x}} \qquad (10\text{-A})$$

It will be noted that the solution of Equation (10-A) for the pressure of CO_2 at any point within the well stream calls for a knowledge of the total weight of CO_2 produced by the well, m, b, etc. The latter two are obtained directly from water analysis data. The other required data, such as the volume of oil, water, gas, etc., also are directly obtainable.

The value of $W_{co_2\text{-}T}$, however, must be calculated. This is done through the use of Equation (10). A value of P_{co_2} can be determined at a surface separator where the CO_2 content is determined analyti-

cally, following which $P_{co_2\text{-}sep} = (\%CO_2)\ (P_{sep})\ 10^{-2}$. The (9-A) portion of Equation (10) must be modified for calculation of $W_{co_2\text{-}G\text{-}sep}$. In this case $V_{G\text{-}sol\text{-}x\text{-}T} = 0$. In addition, the factor $\frac{P_{co_2\text{-}x}}{P_x}$ is made equal to percent $CO_2 \times 10^{-2}$. Substitution of these changes in Equation (9-A) gives:

$$W_{co_2\text{-}G\text{-}sep\text{-}T} = V_{G\text{-}ats\text{-}T} \times \%CO_2 \times 10^{-2} \times \rho_{co_2\text{-}ats} \quad (9\text{-B})$$

where: $V_{G\text{-}ats\text{-}T}$ = Total volume of gas measured from the separator.

Relation (10) modified in accordance with these considerations becomes:

$$W_{co_2\text{-}T} = V_w\ (mP_{co_2\text{-}sep} + b) + 2.62 \times 10^{-3}\ V_o P_{co_2\text{-}sep} + V_{G\text{-}ats\text{-}T} \times \%CO_2 \times 10^{-2} \times \rho_{co_2\text{-}ats} \quad (10\text{-B})$$

The procedure for calculating $P_{co_2\text{-}x}$ is to first solve (10-B) for the total weight of CO_2 produced by the well and substitute this value, together with the other known data in Relation (10-A) and solve for the CO_2 pressure, $P_{co_2\text{-}x}$, where x is the desired depth within the well stream.

Calculation of the Weight of Carbonic Acid in the Water Well from $P_{co_2\text{-}x}$

Having determined $P_{co_2\text{-}x}$ from (10-A), Relation (2) is used to calculate the dissolved CO_2/liter in the well water at point x, and Relation (11) is used to convert this value to gm-mols of dissolved carbonic acid per liter. The relations are:

$$W_{co_2\text{-}w/L} = mP_{co_2\text{-}x} + b \quad (2)$$

$$H_2CO_3,\ \text{gm-mols/L} = 2.28 \times 10^{-2}\ W_{co_2\text{-}w/L} \quad (11)$$

or:

$$H_2CO_3,\ \text{gm-mols/L} = 2.28 \times 10^{-2}\ (mP_{co_2\text{-}x} + b) \quad (11\text{-A})$$

Method of Calculating Down Hole pH of Waters Containing Carbonic Acid and Bicarbonates

The pH of an aqueous media containing carbonic acid depends upon the concentrations of the acid and alkaline constituents. Oil well brines contain calcium and sodium bicarbonates as the alkaline constituents. Calcium bicarbonate is the principal alkaline agent although large quantities of sodium bicarbonate have been found in some California and Venezuelan waters. Few records are available to this laboratory where carbonates or hydroxides are present in oil well waters.

The formation of carbonic acid in water from carbon dioxide in contact with it occurs through the equilibrium relation:

$$\frac{(H_2CO_3)}{(CO_2)} = K_1 \quad (12)$$

In this work unit activity coefficient is assumed and the quantities and equilibrium constants used are stoichiometric values. Equation (12) is a generalized form of (11-A).

Carbonic acid ionizes to form hydrogen and bicarbonate ions. This relation, together with the associated equilibrium constant, is:

$$H_2CO_3 \rightarrow H^+ + HCO^-_3 \quad (13)$$

and:

$$\frac{(H^+)\ (HCO^-_3)}{(H_2CO_3)} = K = 3.0 \times 10^{-7} \quad (13\text{-A})$$

or:

$$(H^+) = 3.0 \times 10^{-7} \frac{(H_2CO_3)}{(HCO^-_3)} \quad (13\text{-B})$$

The bicarbonate ions further ionize to form hydrogen and carbonate ions. This relation, together with the corresponding equilibrium constant, is:

$$(HCO^-_3) \rightarrow (H^+) + (CO^=_3) \quad (14)$$

and:

$$\frac{(H^+)\ (CO^=_3)}{(HCO^-_3)} = K_3 = 6 \times 10^{-11} \quad (14\text{-A})$$

or:

$$(H^+) = 6 \times 10^{-11}\ \frac{(HCO^-_3)}{(CO^=_3)} \quad (14\text{-B})$$

As stated previously, these relations cover stoichiometric concentrations and are only approximate because unit activity is assumed. The use of the more accurate activity values changes Equation (13) to:

$$K_3 = \frac{\gamma\ (H^+)\ \gamma\ (HCO^-_3)}{\gamma\ (H_2CO_3)} = 3.5 \times 10^{-7} \quad (15)$$

where: γ = Activity coefficient

The activity function, γ, is dependent upon the ionic strength of the solution. Oil well brines cover a wide range of ionic strengths for which the necessary activity functions of carbonic acid are not available. It is necessary in this work, therefore, to use the less exact relation, (13-B).

Equation (13-B) states that the pH of solutions containing carbonic acid and bicarbonate ions can be calculated from a knowledge of the ratios of the respective ions present. Oil well brines which contain only carbonic acid and bicarbonate ions as pH controlling compounds have pH values of 8.5 or less. The effect of CO_2 on pH can be calculated through a form of Equation (13-B):

$$pH = 6.8 + \text{Log}\ (HCO^-_3) - \text{Log}\ (H_2CO_3) \quad (16)$$

If sufficient alkaline agents are present to convert the carbonic acid to bicarbonates and carbonates, then only the latter two ions are present and Relation (14-A) is used to calculate pH values. In this case the pH is greater than 8.5, but since this does not normally occur for oil well brines it will not be discussed further.

Equation (16) has been plotted as Figure 5 to show the pH of carbonic acid-bicarbonate solutions at values of bicarbonate concentration ranging from 1×10^{-3} to 1 gram-mole/liter. To determine the pH of a CO_2-HCO^-_3 brine the concentration of carbonic acid in the well water is calculated as shown earlier by Relations (10-A) and (11). The concentration of bicarbonate is most satisfactorily determined by methyl orange titration of a sample of the water after it has come to equilibrium with carbon dioxide in the atmosphere. Such a titration should be made on a sample so handled that any precipitated calcium

carbonate is titrated along with the bicarbonate in solution.

Equation (13) shows that carbonic acid dissociates to form hydrogen and bicarbonate ions. Thus a water under well pressure containing carbon dioxide contains more bicarbonate ions than present under atmospheric conditions when the bicarbonate content is titrated. The ionization of carbonic acid yields equal concentrations of hydrogen and bicarbonate ions, so (13-A) can be put in the form:

$$(HCO^-_3) = \sqrt{3.0 \times 10^{-7}\,(H_2CO_3)} \qquad (13\text{-C})$$

One of the greatest concentrations of carbonic acid calculated for an oil well brine under bottom hole conditions in this study was 20 grams/liter. By Equation (11) the $(H_2CO_3) = 2.28 \times 10^{-2} \times 20 =$ 0.456 gm-moles/liter. Substitution of this value in (13-C) gives a concentration of HCO^-_3 of 0.37×10^{-3} gm-moles/liter, or 23 ppm, which is an insignificant correction. The amount of bicarbonate formed from dissociation of carbonic acid is, therefore, ignored in this study.

By way of interest, Equation (13-A) can be used to calculate the pH of waters containing carbonic acid, but not bicarbonate other than that formed from the dissociation of the carbon dioxide. The relation is:

$$pH = 4.08 + \text{Log}\ \frac{1}{\sqrt{W_{CO_2}}} \qquad (13\text{-D})$$

This relation is shown in Figure 5.

Illustration of Down Hole pH Calculation for H_2CO_3-HCO^-_3 Brine

Assume that a well produces 100 barrels of water and 10 barrels of oil at a gas-oil ratio of 200 to 1. The gas contains 2 percent CO_2 and the top hole pH is 6.75. The bicarbonate content is 61 ppm and b=0. The dissolved gas at the bottom of the hole is 50 cu ft/bbl, and the formation volume factor is 1.0. The water contains 50,000 ppm salt, the well is 5000 feet in depth, and the fluid gradient is 0.40 lbs/ft. The CO_2 was measured in gas coming from a 14.7 psig separator.

$$P_{CO_{2\text{-sep}}} = 29.4 \text{ psi} \times .02 \times 51.7 = 30.5 \text{ mm Hg}$$

The total weight of CO_2 in the well fluids is determined by (10-B) and substitution of the appropriate values of the example gives:

$$W_{CO_{2\text{-T}}} = (100)\,(150)\,(1.23 \times 10^{-3} \times 30.5) + 2.62 \times 10^{-3}\,(10)\,(159)\,(30.5) + (200)\,(10)\,(28.3)\,(.02)\,(1.98) = 2943 \text{ grams}$$

The pressure of CO_2 at the bottom of the well is now determined by (10-A):

$$P_{CO_{2\text{-x}}} = \frac{2943}{(1.23 \times 10^{-3})\,(159)\,(100) + 2.62 \times 10^{-3}\,(10)\,(159)\,(1) + \frac{1.98\,[(200)\,(10)\,(28.3) - (50)\,(10)\,(28.3)]}{5000\,(.40)}} = \frac{2943}{65.8} = 44.7 \text{ mm Hg} \qquad (10\text{-A})$$

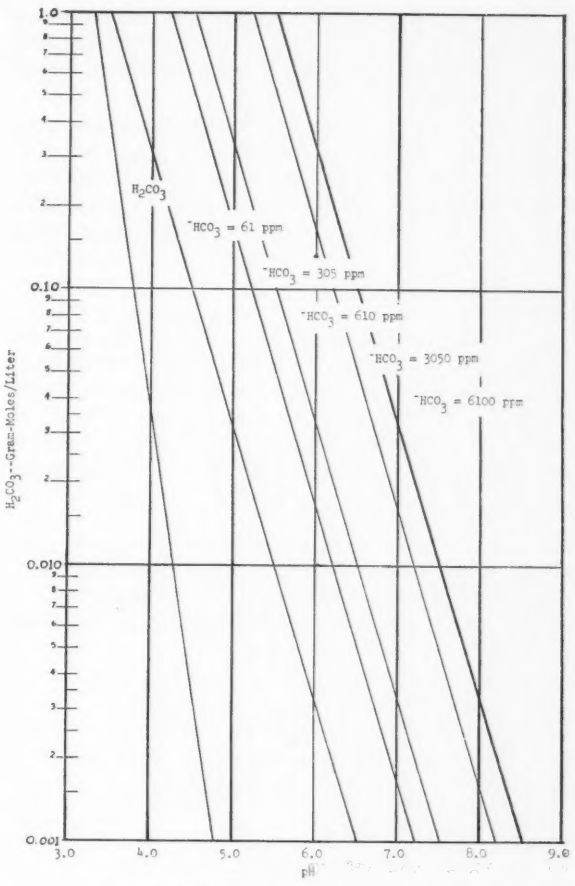

Figure 5—Effect of H_2CO_3 and HCO_3 on pH.

The concentration of H_2CO_3 to be recombined in the well water in gram moles per liter is now determined by (11-A):

$$W_{H_2CO_3} = 2.28 \times 10^{-2}\,(mP_{CO_2} + b) = 2.28 \times 10^{-2} \times .123 \times 10^{-2} \times .447 \times 10^{-2} = 0.125 \times 10^{-2} \text{ gram moles/liter} \qquad (11\text{-A})$$

The necessary data for the bottom hole pH now are:

Bicarbonate concentration = 61 ppm

Carbonic acid, gram moles/liter = 0.125×10^{-2}

Use of these data with Figure 5 shows the pH at 5000 feet to be 6.42, a reduction of 0.33 units from the top hole pH.

Calculation of Down Hole pH of Oil Well Brines of pH Less than 6.7

Theoretically, any water of pH less than 7.0 is acidic. From a practical standpoint and for purposes of this study only well waters with pH values of 6.7

or less under atmospheric equilibrium conditions are considered sufficiently acid to require steps in addition to those just described to calculate the pH value within the well.

Oil well brines of acid pH are fairly common. Many fields along the Texas and Louisiana Gulf Coast produce from multiple reservoirs. It has been found that these will produce waters ranging from approximately pH 6.2 to 6.8. It is necessary, therefore, in such multiple reservoir fields to examine the water from each reservoir to make certain of its pH.

pH values ranging from 6.2 down to 4.9 are found in fields in Mississippi and Alabama. These waters carry high concentrations of salt (i.e., salts in the 100,000 to 200,000 ppm range). Sodium chloride is the major component, with strong concentrations of calcium and magnesium. The hydrolysis of magnesium salts probably aids the reduction of pH below 7.0 but in itself is not always sufficient to account for the total acidity. While no identification of the acidic materials present has been made, it is reasonable to expect the presence of organic acids of the acetic type as accounting for part of the acidity.

Regardless of the cause of the non-volatile top hole acidity, the down hole acidity will be increased through the reintroduction of carbon dioxide lost in the separator or stock tank. The data necessary for the calculation of the down hole pH are:

1. The top hole pH.
2. The bicarbonate content.
3. The amount of carbon dioxide to be introduced into the water.

These are the same data as required for the previous case, and the carbon dioxide to be introduced is calculated in the same manner.

To calculate the bottom hole pH, the top hole pH is converted to an equivalent concentration of carbonic acid having the measured bicarbonate concentration. To this is added the H_2CO_3 to be recombined. From these data the pH is read from Figure 5.

Calculation Method for Down Hole pH of Condensate Waters

The calculation of the down hole pH of condensate waters is performed in a similar manner to that of acid oil well brines. The main characteristics, however, are such as to warrant separate discussion.

Condensate reservoirs contain hydrocarbons and water vapor in a single phase condition. Upon release of pressure, as the single phase fluid passes up the flow string of the well, retrograde hydrocarbon condensation occurs. As the pressure is reduced the temperature of the well fluid falls and water and further quantities of hydrocarbons are condensed. When the well stream leaves the well head and enters the separator, further reductions in temperature and pressure occur and further quantities of water and hydrocarbons are condensed.

It is of importance from corrosion studies that the condensate-water ratio obtained in the separator is not the condensate-water ratio in the well. True condensate water, therefore, condenses from a gaseous phase and should not carry dissolved salts. Many condensate waters meet this specification and are produced with very low quantities of the normal oil field salts. These waters do, however, absorb carbon dioxide and organic acids from the well fluids, resulting in their being strongly acid in many cases. For purposes of this discussion, condensate waters are those which contain less than 2000 ppm of sodium chloride, the division being purely abritrary. These acid waters react with the steel tubular goods of the well and contain upwards of several hundred ppm dissolved iron at the well head. Reaction of the acids with the iron results in neutralization of some of the acid, and the waters at the well head have pH values above the minimum in the well.

The recalculation of the down hole pH value of a condensate water consists of two operations. One is the adjustment of the pH resulting from the neutralizing effect of the dissolved iron. The other is the effect of reintroducing the CO_2 lost in the separator and stock tank. The effect of neutralization by iron is easily accomplished by allowing the iron to oxidize to the ferric condition. This is done by aerating the water through exposure to air. The iron is precipitated as ferric hydroxide and the acid anion reforms the free acid. To this water is recombined the lost CO_2 for minimum down hole pH.

The total amount of CO_2 produced by a condensate well is often times simpler to calculate than for an oil well. This results from the fact that the gas phase is large in volume while the oil and water phases are small. Thus, in most cases the total CO_2 production can be taken as the amount of CO_2 in the gas. The calculation then becomes:

$$W_{CO_2\text{-}T} = V_{G\text{-}ats\text{-}T} \times \%CO_2 \times 0.0198 \qquad (10\text{-C})$$

Within the well the liquid hydrocarbons are laid down as the pressure and temperature are decreased. These increase in volume instead of decreasing, as do crude oils during production. At great depths in the well the liquid hydrocarbon volume is low in comparison with the gas volume, and insufficient CO_2 is absorbed to alter appreciably the value of $P_{CO_2\text{-}x}$ from what it would be in the gas phase if no hydrocarbons were present. Accordingly, the value of $P_{CO_2\text{-}x}$ is calculated:

$$P_{CO_2\text{-}x} = P_x \times \%CO_2 \times 10^{-2} \qquad (10\text{-D})$$

The weight of carbonic acid dissolved in the water at point x then becomes by (11-A):

$$W_{H_2CO_3} \text{ gram mols/L} = 2.28 \times 10^{-2} (mP_{CO_2} + b) \qquad (11\text{-A})$$

The value of m for condensate waters can be taken as 1.42×10^{-3} and $b = 0$. The weight of H_2CO_3 in the water becomes:

$$W_{H_2CO_3} \text{ gram mols/L} = 3.24 \times 10^{-5} P_{CO_2} \qquad (11\text{-B})$$

Once the percent of CO_2 in the separator gas is

determined, and the well pressure at the point where the pH is to be determined is known, the use of Relations (10-D) and (11-B) permit calculation of the CO_2 dissolved in the well water at the point in question.

It must be remembered that it is only when the volumes of water and liquid hydrocarbons produced by a condensate well are small in comparison with the gas produced that the simplifying equation presented above can be used. If the volumes of condensate and water are large the full procedure for determination of the value of $P_{CO_{2-x}}$ must be used.

Determination of the down hole pH of condensate waters is carried out in exactly the same manner as for the acid oil well brines. The final required data are the top hole pH, the bicarbonate content, and the weight of H_2CO_3 to be recombined in the water, the latter as calculated by Equation (11-B). Having these data the equivalent H_2CO_3 content of the water at the well head is determined through the intersection of the well head pH on the proper bicarbonate curve of Figure 5. The down hole pH is then determined by following the bicarbonate curve to the down hole total H_2CO_3 value.

As in the case of acid oil well brines, the reintroduction of CO_2 into an acid condensate water may not greatly affect the well head pH.

Comparison of Top Hole and Calculated Bottom Hole pH Values

Utilizing the method developed in this article, a number of pH values under bottom hole conditions have been calculated. The results range from values equal to those measured at the top of the hole to values showing considerably increased acidity. The variations demonstrate the fact that wherever the pH of a well fluid to be considered in connection with the well corrosion rate, the pH should be calculated at the point in the well where the corrosion occurs.

TABLE 1—Measured and Calculated pH Values

FIELD	Type Well	Percent CO_2 In Gas	Experimentally Determined Top Hole pH	Calculated Bottom Hole pH	Difference (pH Units)
East Texas	Oil	2.4	6.80	6.50	0.30
N. Louisiana	Oil	1.7	6.65	5.55	1.10
Mississippi	Oil	1.0	5.05	5.05	Zero
Venezuela	Oil	1.2	7.10	6.75	0.35
Venezuela	Condensate	12.0	6.30	4.95	1.35
California	Oil	39.0	8.50	5.85	2.65

Table 1 gives a comparison of some measured and calculated pH values demonstrating the variations found.

Acknowledgment

The writer expresses his appreciation to the management of the Gulf Oil Corporation, Houston Production Division, for permission to publish this paper, and to his co-workers, H. E. Waldrip and J. A. Rowe for their aid in its preparation.

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2. W. F. Rogers, J. A. Rowe, Jr. and P. J. Kalish. Laboratory Apparatus for Studying Oil Well Subsurface Corrosion Rates and Some Results. *Corrosion*, **9**, 25, (1953) Jan.
3. W. F. Rogers and J. A. Rowe, Jr. Corrosion Effects of Hydrogen Sulfide and Carbon Dioxide in Oil Production. 4th World Petroleum Congress, Section 2, Rome, Italy, June, 1955.

Any discussions of this article not published above will appear in the June, 1957 issue.

Underground Aluminum Gas Line*

By R. S. DALRYMPLE

Introduction

ONE OF THE first buried aluminum gas lines to be put in service in the United States was installed near Listerhill, Alabama, in March of 1950. The line was built to supply natural gas to the Listerhill Plant of the Reynolds Metals Company. It was joined to the main trunk line of the Alabama-Tennessee Natural Gas Company, a nearly straight run of 1.8 miles.

The pipe for the line was produced in 40 foot lengths by the Reynolds Metals Company by hydraulic extrusion of alloy 6063 and was heat treated and aged to the T6 temper. The extruded pipe was 8¾-inch (outer diameter), with a ¼-inch wall, and designed to operate at 500 psig.

The pipe sections were prepared at the mill for welding by making a 30 degree bevel on each end thus eliminating the necessity for any field preparation. Welding was performed by the inert arc process using Alloy 4043 filler rod. Further details on welding of this pipe line are contained in an article by W. B. Moore.[1] Welding, as well as other handling problems, were greatly facilitated by the light weight of the aluminum pipe (320 pounds per 40 foot section as compared to 950 pounds for conventional steel pipe.)

After welding, the entire length of the pipe line was protected by: (1) Coating with a grease type sealant followed by (2) A wrap of dielectric material. The coated pipe was then placed in the trench and backfilled.

Connection of the aluminum pipe line to the steel pipe line was made by means of flanges using an insulating gasket and insulated bolts. No electrical tie was made with the existing steel pipe line.

In addition to the 1.8 miles of coated aluminum line, a 40 foot section of unprotected aluminum pipe was buried on the property of the Alabama-Tennessee Natural Gas Company meter station for the purpose of studying soil corrosion on bare and unprotected aluminum pipe. This section of unprotected aluminum pipe is a part of the line supplying the Reynolds Metals Company, but is electrically insulated from that line by means of insulating gaskets. By means of a bypass it may be taken out of service for examination without interrupting the supply of gas to the Reynolds Metals Company.

Approximately one month after the wrapped aluminum pipe was installed, a cathodic protection survey was performed. The coating resistance of the extruded aluminum pipe was found to be 25,250 ohms per square foot. This value is lower than for any section of the enameled 10 inch steel main line employed in this distribution system, but is considered good for the type of wrap employed.

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Abstract

A protected and an unprotected length of aluminum gas line pipe were buried at the same time and put into use. The longer length was protected by coating with a grease type sealant followed by a wrap of dielectric material; the shorter length was put into the ground unprotected. One month after the wrapped aluminum was installed a cathodic protection survey was performed. By means of a field test it was determined that a current requirement of only 97 milliamperes polarized the aluminum line from a potential of —0.85 volt to —1.00 volt referred to a saturated copper sulfate electrode.

The two lines were dug up at the end of five years and examined for corrosion. The insulating gaskets of the unprotected pipe line were found to be in good condition; the unprotected line was superficially stained over its entire length but the stain was of no significant depth. In spite of these findings the author thought it necessary in future operations to adequately coat aluminum lines and to supply the modest requirements for cathodic protection in order to eliminate the hazards of soil corrosion and electrolytic corrosion. 2.2.6

Soil resistivity is generally high along the right-of-way. With the exception of one small region located 800 feet from the gas company meter station, where a soil resistance of approximately 4000 ohm-cm was measured, the line is buried in soil having an electrical resistance in excess of 10,000 ohm-cm.

By means of a field test it was determined that a current requirement of only 97 milliamperes polarized the aluminum line from a potential of —0.85 volt to —1.00 volt referred to a saturated copper sulfate electrode. Application of a protective current over a long period of time will polarize a metal structure to a protective potential with a much lower value of current than is indicated in short time cathodic protection tests. Consequently, the cathodic protection system for this line was designed to supply only 40 ma of protective current which, because of gradual polarization of the pipe, was predicted to

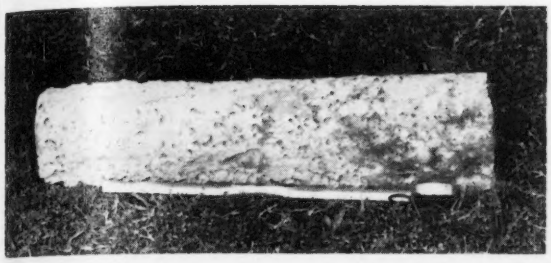

Figure 1—Magnesium anode after five years service protecting buried aluminum gas line.

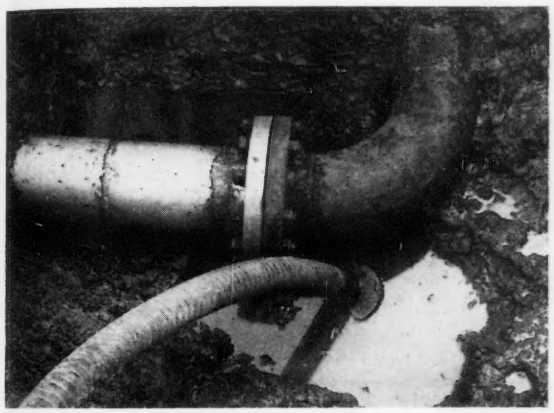

Figure 2—Flange section on 1.8 mile buried aluminum gas line. The grease type coating and protective wrap were removed for the examination.

result in a pipe to soil potential of —0.95 volt. The veracity of this prediction was borne out in field measurements. The cathodic protection system consisted of six magnesium anodes, buried at 15 foot intervals at a five foot depth in a line perpendicular to the aluminum pipe line and located in soil with an electrical resistance of 4000 ohm-cm.

Unprotected Pipe

In March of 1955 the unprotected 40 foot section of aluminum pipe line and the insulated joint between the steel gas supply line and the 1.8 mile aluminum line at the Gas Company metering plant were unearthed and exposed for examination. Pipe-to-soil measurements using a copper-copper sulfate electrode at the time of this examination revealed the following voltages:

Coated and cathodically protected aluminum pipe: .....—0.95 V

Bare unprotected steel: .....—0.54 V

The corrosion potential of the unprotected aluminum pipe could not be measured as it had been completely unearthed.

One of the magnesium anodes was removed from service and examined. It was pitted on the surface as shown in Figure 1, but the overall dimensions were virtually unchanged.

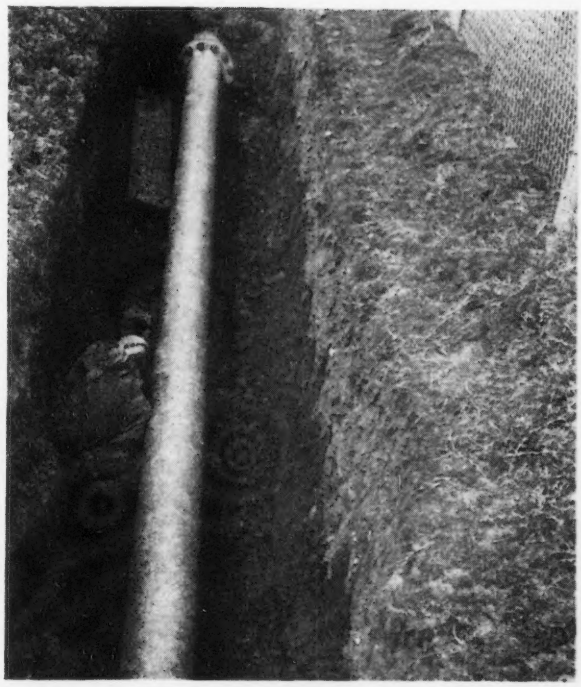

Figure 3—View of portion of unprotected pipe after five years service.

Figure 4—Closeup of surface on section of buried unprotected aluminum gas line after five years service.

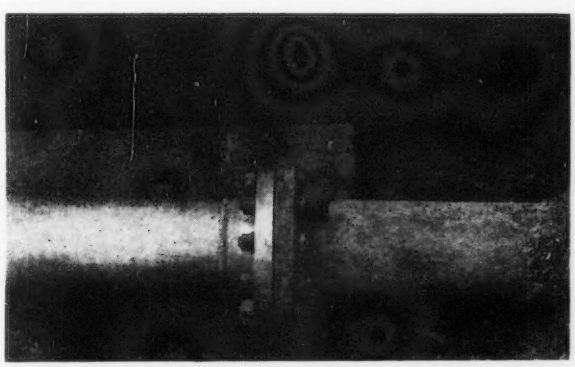

Figure 5—Flanged insulating connection between the unprotected aluminum gas line and a steel line under cathodic protection.

A visual examination of the flange section of the main aluminum 8 inch line disclosed no evidence of corrosion, and as indicated by electrical measurements, the insulation at the flange is still in excellent condition. Figure 2 is a photograph of the exposed flanged joint after the pipe wrap and grease coating were removed. The enameled steel pipe, although not under cathodic protection, is free of corrosion—at least at the exposed end.

The unprotected (not coated or cathodically protected) section of aluminum pipe line was examined in its entirety. Electrical measurements disclosed that the insulating gaskets were in good condition which probably precludes any protection of the aluminum line by cathodic protection applied to the steel pipe. The aluminum line was superficially stained over its entire length as may be observed in Figures 3, 4, and 5. This stain was of no significant depth and should be construed as a surface discoloration rather than as a corrosive action that will limit the life of the pipe.

As a result of this examination it was concluded that the extruded 8 inch aluminum pipe line of alloy 6063 is performing in an outstanding manner and possesses a virtually unlimited life, at least from soil corrosion effects.

In this location, Florence, Alabama, and in this particular service, it apparently would not have been necessary to protect the aluminum pipe line to realize a long and useful, trouble-free life. All the same, unless there are test data to the contrary, it still is considered necessary to adequately coat aluminum lines and to supply the modest requirements for cathodic protection to eliminate the hazards of soil corrosion as well as the ever-present dangers of electrolytic corrosion resulting from stray current pick up from nearby pipe lines which are under cathodic protection.

Acknowledgment

The author expresses his gratitude to the Alabama-Tennessee Natural Gas Company, and especially to L. C. Bartmess, Chief Engineer, for assistance in obtaining the information contained in this report.

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Any discussions of this article not published above will appear in the June, 1957 issue.

Part 2 of 2 Parts

Properties, Specifications, Tests And Recommendations for Coal Tar Coatings*

Part 2—Cold Applied Coatings

By W. F. FAIR, JR.*

Abstract

Principal characteristics of cold applied coal tar coatings are considered with respect to applications. After reviewing the prerequisites of surface preparations, criteria for selection with respect to the exposure are considered. Five classes of coatings produced by one or more manufacturers are itemized and their general characteristics outlined. Care in selection of primer is emphasized and types of acceptable primers to be used under coal tar coatings mentioned.

After reviewing briefly the problem of water vapor permeability the author discusses the theory of transmission and gives definitions of transmission rate, permeance and permeability. Methods whereby these characteristics may be evaluated with respect to a specific coating are given. Results of an investigation of vapor transmission rates for three classes and one system of coatings are tabulated. Permeance of commonly used building materials is tabulated.

Recommended coal tar systems for numerous exposures of piling, pipe, and other metal structures are given. 5.4.5

Introduction

FREQUENTLY it will not be convenient to apply hot coatings at a particular installation, or for other reasons the customer may restrict the protective material to cold applied types. Furthermore, it is often more feasible to apply cold coatings to above ground structures. To provide light to heavy duty cold applied bituminous coatings, several manufacturers now produce a comprehensive line of such coatings covering a wide range of viscosities, and of recommended types of installations.

The basic materials for these coatings are the coal tar materials discussed in Part 1,[1] made fluid by incorporation in coal tar solvents. After application and evaporation of solvent, the residual films should approach those of the hot applied equivalent coatings in viscosity, yield value, adhesion, water absorption, and oil spillage resistance. The cold applied coatings usually are used on structures exposed from mild to extremely severe corrosive atmospheres, including marine as well as chemical environments.

Surface Preparation

It has been stated many times that corrosion begins on the drawing board. This of course is just another way of saying that much of the trouble encountered in corrosion prevention starts with faulty planning of the initial project. At a symposium on Modern Metal Protection, Seagren[2] concluded that "it is not necessary that a design engineer be familiar with all types of organic coatings, but it is highly desirable that he have an understanding of the fundamental corrosion processes and of the mechanics of corrosion prevention by means of organic coatings. Equipped with such information the engineer will consider corrosion prevention as another problem in design. Too frequently corrosion protection is only a necessary afterthought. Many of the difficulties with which organic coating technologists are confronted might have been avoided on the drawing table."

No matter what type of coating is used to protect a metallic surface, it is absolutely essential that all surfaces be thoroughly cleaned before application of the coating. The surfaces should be completely free of moisture, mill scale, welding scale, rust, grease, dirt, and corrosion products or any other foreign matter. NACE[3] and the Steel Structures Painting Council[4] have separately issued reports and recommended procedures covering this important field.

Types and Characteristics of Coatings

The coating system specified should have adequate resistance for the particular corrosive environment, at the lowest cost of materials and application for the service life anticipated.

The properties of the coatings themselves also should be considered. At the time of application the adhesion and viscosity of the coating must be suitable to provide the proper required thickness and subsequent adherence to the coated surface; also, the film must prevent corrosion and have a suitable drying rate. The dried coating must have satisfactory adhesion throughout the range of service conditions expected and must have appropriate flow properties to provide permanence on the surface, adequate thickness, impermeability, elasticity, and satisfactory weather resistant properties.

The viscosity of the coating both during application and after film formation is very important. The satisfactory application and subsequent behavior of the applied coating may depend to a great extent upon the rheological properties of the particular formulation selected.

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* Coating consultant, Kopper Company, Inc., Tar Products Division, Verona, Pa.

Some materials may behave like non-Newtonian liquids as described earlier in Part 1, and in addition also may exhibit properties known as thixotropic. A thixotropic material may be defined as one that undergoes reversible sol-gel transitions without change in composition. In other words, mechanical agitation will destroy temporarily the so-called false body of these products rendering them sufficiently fluid for easy application; after application or after remaining in a container undisturbed, they quickly revert to their non-flowing high consistency form. Because of these unique properties thixotropic coatings may be applied economically in extremely thick films thereby providing a substantial increase in corrosion resistance. Extremely interesting developments in the field of cold applied coal tar coatings have resulted in formulations and processes for making certain coatings which exhibit thixotropy to a high degree, permitting application of barriers many times as thick as are possible with conventional paint films.

It should be noted that the applied coating must be initially of the thixotropic type if especially thick coatings are specified upon application to provide protection against particularly corrosive service conditions. It is, of course, necessary to clean the surface to be protected, as emphasized above, before application of the selected coating.

The types of cold applied coal tar base protective coatings generally available may be summarized by separation into the following groups.

Class (1)

Materials of this group are unfilled relatively fluid self-leveling cutbacks intended for light to moderate corrosive environments, especially on surfaces easily accessible for periodic inspection and maintenance. The pitch base usually has a Ring & Ball softening point of about 140 F to 150 F, and the solvent should be a coal tar distillate boiling between 150 C to 200 C. Coverage obtained should be of the order of 400 square feet per gallon per coat, giving a dry film thickness of about 2 mils per coat. The hard glossy black film will protect the underlying surface from fumes, water, and air at atmospheric temperatures. This type should not be applied to surfaces exceeding 400 F (dry), or 100 F (immersed).

Application: These coatings may be applied by brushing, spraying, roller coating, or dipping. Class (1) products can be sprayed with ordinary, vacuum-type equipment, using a minimum air pressure of 12 pounds per square inch, but pressure pot spray equipment is generally employed and is to be preferred. Following are the conditions recommended for satisfactory use, using pressure pot equipment:

Atomization Air Pressure.....50 psi
Fluid Pressure.....20 psi
Air Hose.....⅜" to ½" Inner Diameter
Material Hose.....⅜" to ½" Inner Diameter
(Lined with solvent-resistant neoprene)

The following guns are satisfactory for spraying:

Binks Manufacturing Company: Gun No. Thor 7 (36 x 36P)—external atomization.
The DeVilbiss Company: Gun No. MBC with No. 56 cap and E nozzle.
Paasche Air Brush Company: Gun No. CUFP 2-12 with No. 2 tip—external atomization.
The Stewart-Warner Corporation: Hand Gun—No. 7815-C; Pole Gun—No. 7811.
Beach: BS-45 or BP-45

Typical Specification: CTP-3 Coal Tar Paint, Bureau of Reclammation.

Class (2)

Coatings of this group also are made from straight distilled coal tar pitches cutback with the same coal tar solvent naphtha, but in addition contain substantial amounts of finely divided inert mineral filler. The products are more viscous, approximately five times more heavily bodied than paint or varnish. The material is intended for heavier application and more severe environments. It is usually applied at a rate of 100 to 150 square feet per gallon per coat, yielding a black non-glossy dry film of about 8 mils thickness per coat. Care should be taken to ensure that a non-settling product is procured when this type is under consideration. Service temperatures are identical with Class (1), but this coating may be used with wrappers below grade up to 150 F, if desired.

Application: These coatings, after thorough stirring, may be applied by brushing, roller coating, or spraying. A heavy duty pump is needed for spray application, which requires the following conditions:

Atomization Air Pressure.....50 to 90 psi
Material Pump Air Pressure.....35 to 90 psi
Hose Requirements.....Material ¾"
Air—⅜" to ½"
Material Hose: 1000-pound brush pressure hose required. Petroleum and solvent-resistant neoprene reinforced with heavy rayon cord. (Alemite hose or equivalent recommended.)

The following pumps have been found to be satisfactory:

The Stewart-Warner Corporation: No. 7804-E Versatal Heavy Duty Pump.
Lincoln Engineering Company: Standard 4 Inch Pump No. 1889-A.
The DeVilbiss Company: QBD 609 Pump Unit.
Gray Company: Grayco No. 202798 Pump (8 to 1 ratio).
Binks Manufacturing Company: Heavy Duty Pump (7 to 1 ratio) A-72.
The Aro Equipment Corporation: No. 2803 M. Undercoater.

The following guns are satisfactory for the atomization of Class (2) materials:

Binks Manufacturing Company: (1) Gun No. Thor 7-E-1 (Internal atomization—flat spray). (2) Model 25 Extension Gun.
The DeVilbiss Company: Gun No. MBC 565 ¼ Inch R. D. Spray.
Eclipse Air Brush Company, Inc.: Gun No. GAT-C (heavy duty with 3/16 inch tip and No. 27 CT nozzle—slotted).
Paasche Air Brush Company: Gun No. DURIF 2-12 with No. 8 tip and 0.045—3 cap.
The Stewart-Warner Corporation: Hand Gun—No. 7815-A; Pole Gun—No. 7811.
Lincoln Engineering Company: Gun No. 66744.
Gray Company: Hand Gun—No. 101064; Pole Gun—No. 202306.

There is no General Specification for this type.

Class (3)

This type of coating is based on a plasticized coal tar pitch similar to that used to produce plasticized

enamels. Properly fluxing with coal tar solvent naphtha and incorporating mineral filler produces a heavy paste which exhibits thixotropic properties to a marked degree. Because of this thixotropic character these products can be applied in thick films without sagging or running. Application at the rate of 55 to 70 square feet per gallon produces a dry film approximately 20 mils thick. The thick, dull, black dry film, after evaporation of the solvent, approaches the hot applied plasticized coal tar enamels in many service properties. For this reason it is frequently used underground with wraps or shields, if for any reason it is undesirable to apply a hot coating. These coatings should not be used for service temperatures above 160 F (dry) or 100 F (immersed), nor below —20 F.

Application: After rendering fluid by agitation *only*, these products may be applied by brushing (trowel fashion), roller coating, or spraying. For the latter, the conditions and equipment required are the same as for Class (2) materials.

Typical Specifications: CA-50 Coal Tar Paint, Bureau of Reclamation; MIL-C-18480-(1).

Class (4)

This group contains aqueous dispersions of pitches, usually with added filler. By dispersing the pitch base in water to produce an homogeneous emulsion, the use of cutback solvents is avoided. The products are viscous, essentially dark brown to black, and dry to a flat dull dark gray color. Although of high consistency, these emulsions are also thixotropic, and may be easily applied at rates of 50 to 60 square feet per gallon, producing dry films of about 14 mils thickness per coat. Containing substantial amounts of water, these coatings present no fire hazard, but they may be affected by sudden rain soon after application before they have set up. After setting up, they are satisfactorily resistant to the elements, but their use under continuous immersion conditions is not recommended.

Resistance to flow at elevated temperatures, and resistance to combustion make these products particularly suitable for certain types of service. The dry coating withstands service temperatures of —50 F to 200 F, and has been used under conditions of flash temperatures (dry) up to 500 F.

Freezing of these products must be avoided during storage and for the first few hours after application. Some varieties are now made to be freeze-thaw stable, which eliminates inventory and shipping problems in cold weather, but even these modified types should not be applied at sub-freezing temperatures.

Application: Since freshly cleaned metal is very active chemically, a primer should be used before the emulsion, as described later. After reducing the consistency by agitation these coatings may be applied under the conditions, and with the same equipment, as recommended for Classes (2) and (3).

Typical Specification: MIL-C-15203.

Class (5)

Another type of coating required by some consumers is a cold applied coal tar coating which can be used in water lines, water tanks, air conditioning ducts, and the like to protect the metal surfaces without imparting taste or odor to potable water or interior atmospheres. This fluid coating made with selected pitches and solvents to meet the above requirements greatly resembles Class (1) coatings in appearance and in physical properties. Coverages of the order of 400 square feet per gallon per coat are usually obtained on clean metal surfaces.

Application: Same as for Class (1) Coatings.

Typical Specification: AWWA D102-54T, Sec. 5.4.6.

Primers—Compatibility

Except for the Class 4 emulsion, the coal tar coatings just discussed are all self-priming, and should be applied to the clean bare metal directly, immediately after cleaning. Not only should it be noted that in general primers are not needed to effect good adhesion of the dried film to the metal surface, but in many instances they cause poor adhesion and rapid failure of the coating system. The solvents necessarily used to dissolve or disperse coal tar residuals in making these coatings have to be of a highly aromatic, high solvency type. When coatings containing these solvents are applied in thicknesses of the order of 8 to 20 mils per coat, the solvents evaporate very slowly from such thick films and hence contact any previously applied dry primer for considerable lengths of time.

The attack of heavy coating solvent on the primed residual film usually results in softening of the primer and slippage of the topcoats, or of the entire protective coating system.

Tar technologists have cooperated with research personnel of the paint industry and have not been able to develop a non-bituminous primer safe from attack by these solvents, except as noted below.

The more fluid coal tar solvent cutbacks (Classes 1 and 5) which are applied at high rates of coverage and hence have relatively thin films (hardly more than two or three times the thicknesses usually obtained with conventional paints) set up more quickly and cut down contact time. Also they may be used with previously selected and tried and approved non-bituminous primers such as red lead primers having vehicles formulated to be high in resins and low in oil.

Another exception may be found in the use of coal tar emulsions or dispersions over certain non-bituminous primers. If an inhibitory pigmented primer is desired, it should be tested in combination with the particular emulsion under consideration; it is quite likely that the emulsion, which should contain no high solvency solvent will adhere to the primed surface without undesirable softening of the film left by the primer. Otherwise a cutback tar primer or one of the self-priming coal tar coatings should be used under the emulsion.

One type of non-bituminous primer, which should be more appropriately described as part of the metal conditioning system rather than as a primer, may

safely be used with cold applied coal tar top coats, namely Wash Primer.

Under the title "Some Recent Developments in Synthetic Resins for Protective Coatings," Whiting[5] describes the successful attempt to produce a coating that would serve both as an inhibitive wash coat and a temporary anti-corrosive primer. This product generally known as "Wash Primer" is an alcohol solution of polyvinyl butyral resin, pigmented with insoluble zinc chromate, with phosphoric acid being added before primer application.

Coal tar coatings may be applied over Wash Primer which is advisedly specified if for any reason the selected coating cannot be applied quickly enough to the cleaned surface, or if the surface can be cleaned but not entirely or satisfactorily dried. It should be noted that Wash Primer does not replace the primer of non-bituminous paint systems.

Recently another type of inhibitory pigmented primer which may have possibilities for use in combination with coal tar top coatings, has been under consideration. These are the epoxy formulations which appear to be far more resistant to the high solvency cutbacks than are the phenolics, alkyds, and vinyls previously tested. To make use of the resin formation to provide a primer film, the epoxy vehicle is mixed with an amine catalyst just prior to application. The catalyst increases the speed of polymerization, resulting in formation of the desired hard resinous film. Although it may be premature to describe test work on these primers, it may be stated that encouraging results are being observed.

It may be stated also that of the many formulations tried in combination with heavy duty, heavily applied coal tar coatings, certain epoxy resin formulations give promise of satisfactory compatibility with coal tar products. It is wise to be conservative in specifying or recommending epoxy resin primers indiscriminately with any kind of bituminous topcoats. Consumers interested in this type of protective system should be advised that such combinations may still be considered to be on an experimental scale. They particularly should be advised that they should contact the manufacturer of the bituminous coating involved to get recommendations on the compatibility of the coating with epoxy resin primers in general, and with any specific ones that the coating manufacturer recommends for joint use with the coal tar top coating.

When a shopcoat is desired to protect structural members during shipment and storage, prior to field coating, the advice of the coating manufacturer on the kind of coal tar base shopcoat recommended should be carefully followed.

Surface Alligatoring

It has been well established that many cutback bituminous coatings tend to alligator upon exposure to intense sunlight and attendant black-body temperature rise. It has also been found that pitch emulsions not only do not alligator when applied alone in two or more coats, but also provide non-alligatoring protection when applied over the heavy duty thixotropic cold coatings, or even over hot applied coal tar enamels. Either of these dual systems are exceptionally good in providing long lasting protective combinations for the most severe atmospheric corrosion envionments.

Application of Cold Applied Coatings As Vapor Barriers

Current widespread interest in this field has been caused by recent building trends, especially those concerned with refrigeration, heating, air conditioning, and insulation. Water vapor will pass through certain materials very readily. Whenever it comes in contact with areas within structures having a temperature below the dew point, it forms moisture or frost which causes the underlying structures to deteriorate. This has necessitated extensive research in developing test methods and materials which are suitable vapor barriers. The cold applied coatings are finding extensive use in the application.

Water Vapor Permeability

The rate of water vapor *transmission* (WVT) of a sheet or film surface is the time rate of water vapor flow, under steady conditions through a unit area. An accepted unit is one grain per square foot per hour. (1 pound = 454 grams; 1 gram = 15 grains.)

The water vapor *permeance* of a sheet or film is the ratio of WVT to the vapor pressure difference between its two surfaces. An accepted unit is the "perm" or one grain per square foot per hour per inch of mercury (vapor pressure difference).

Water vapor *permeability* of a homogeneous material is a property of the substance. This property may vary with conditions of exposure. It is defined as the mathematical product of the permeance and the thickness. An accepted unit is the perm-inch, or one grain per square foot per hour per inch mercury per inch thickness.

There are two generally accepted methods of determining the above-defined properties, known as the wet cup and the dry cup, respectively. In the latter, the specimen under test is sealed to the opening of a cup containing a known amount of material selected for its ability to absorb water. The assembly is then placed in a test chamber or room controlled to pre-selected conditions of temperature and relative humidity. From the gain in weight of the test assembly the water passing through the test material in vapor form can be determined, and since the other variables are known from the established conditions of test, the transmission rate, the permeance, and the permeability of the material can be readily calculated.

In the wet cup method, water is substituted for the dessicant, and the rest of the procedure is identical, but here loss in weight indicates the vapor passing through the material. Some experts claim that the wet cup method is more severe (i.e., that it gives higher water vapor transmission rates than does the dry cup test under identical conditions). It should be noted that a vapor barrier material that is affected by liquid water should never be tested by the wet cup method, nor should such a material be specified if there is any likelihood of wetting by liquid water. This is one of the chief reasons why committees of the American Society for Testing Materials are

working on standardization of both methods as alternate procedures. Similarly, different alternate relative humidities and temperature are suggested for test conditions to cover different ranges which the test materials may ordinarily encounter in service.

The Koppers Company, Tar Products Division, sponsored a research project at Pennsylvania State University to determine the water vapor transmission rates of certain cold applied tar base, heavy duty coatings, conforming to materials of Classes (2), (3), and (4), above. This project was placed under the supervision of Professors F. A. Joy and E. R. Queer.

The work was done on samples made to conform to customary thickness recommendations, the variables being brush and spray application, and one-coat and two-coat jobs. To make the test conditions even more severe and more comparable with service conditions of alternate wetting with liquid water and drying, it was decided to invert the test cup momentarily at each weighing to provide a wet coating without hydrostatic pressure. The results reported are given in Table 1.

For planning and design purposes for two-coat spray applications, the values given in Table 2 may be assigned to these types of products.

Materials classified as vapor barriers by the U. S. Bureau of Standards are those which have a permeability rate not exceeding 1.25 grains per square foot per hour per inch of mercury or 1.25 perms (one perm equals one grain per square foot per hour per inch of mercury). A value of one perm is considered entirely satisfactory for many structures. Lower values possibly down to 0.1 perm might be deemed expedient where high temperature differentials exist, such as in cold storage warehouses in warm humid climates. In any case the values found for these products demonstrate the protection these coatings can provide. This applies not only to the earlier proven protection of metals achieved by insulating them against contact with liquid water, but also to the protection gained when the coating acts as an efficient vapor seal to prevent penetration of water vapor. Such water vapor by its physical presence can disrupt materials, or blister paint films, or by condensation subsequent to penetration, can cause corrosion of metals. It also can cause the destruction by rotting of non-metallic materials or even nullify the insulating value of insulation merely by its presence in the liquid state. It should be noted that a vapor barrier is generally applied as close as possible to the vapor source. When a temperature difference exists the vapor barrier must not be colder than the dew point at the vapor source.

Values customarily used for other common building materials are tabulated in Table 3 for comparison.

Information in the technical literature of other bituminous materials is usually found to cover only the "mastic" type. Such materials require thicknesses in the order of 125 to 250 mills to reach permeance values equivalent to that of the Class 3 coating above.

Tie Coating

Another type of recently developed cold applied coal tar base coating having a rather unusual use is in the field of protection of creosoted railroad ties. Several railroads have found that while properly pressure treated ties will last for many years as far as rot or fungus attack is concerned, they tend to fail from mechanical cracking and the subsequent entrance of water. With alternate drying and wetting, and possible freezing, the cracks in the tie are enlarged. A heavy duty coal tar base coating especially formulated to be fire retardant over which small aggregate is cast, literally puts a weather resistant roof on the tie. From evidence now available this definitely adds years of service life to the creosoted railroad tie. Possibilities of using such coatings over wood in various kinds of structures subjected to weather deterioration may be explored in the future.

Recommendations

Recently a tabulation was made to give some illustrative systems which might be of interest to sales engineers and to customers. Following are recommendations generally intended for the more corrosive atmospheres. It is believed that the combinations listed or their equivalents should provide adequate

TABLE 1—Summary of Results—Vapor Transmission Rates[1]

COATING	Coverage (Sq. Ft./Gal.)	Dry Film Thickness (Mills)	Permeance (Perms) (Wet Cup Method)
CLASS 2:			
1 coat brushed	160	7	0.16
2 coats brushed	80	14	0.08
1 coat sprayed	80	14	0.11
2 coats sprayed	40	28	0.07
CLASS 3:			
1 coat brushed	60	19	0.024
2 coats brushed	30	38	0.015
1 coat sprayed	60	19	0.024
2 coats sprayed	30	38	0.015
CLASS 4:			
1 coat brushed	60	11	0.85
2 coats brushed	30	22	0.89
1 coat sprayed	60	11	1.30
2 coats sprayed	30	22	0.90
First Coat: CLASS 3: **Second Coat:** CLASS 4			
Both coats brushed	60/60	..	0.028
Both coats sprayed	60/60	..	0.025

Note: Specimens with a single coat were included in these tests for purposes of information only. Only two coat jobs are recommended by the manufacturers and consulting engineers.

[1] Pennsylvania State University data.

TABLE 2—Permeance and Dry Film Thickness of Coatings

COATING	Dry Film Thickness In Mills	Permeance (Perms) (Wet Cup Method)
Class 4	22	0.90
Class 2	28	0.08
Class 3	38	0.02
Class 4 over Class 3	30	0.03

TABLE 3—Permeance of Building Materials

MATERIAL	Thickness (Mills)	Permeance (Perms)
30-Pound Saturated Felt	30	1
¾-inch Plaster (no paint)	750	32.9
Aluminum Foil	..	0.09
Builtup Roofing	1000+	0
Waterproof Membranes	500	0
Ordinary House Paint—2 Coats	3-4	1.14
Ordinary House Paint—3 Coats	4-6	0.90
25/32-inch Coated Insulation Board	800	8.7
½-inch Asphalt Treated Gypsum Sheathing	500	29.3
Class 3—2 Coats	38	0.02

protection for the kinds of services described. The cold coatings are designated according to the classes given above. The plasticized or unplasticized enamels selected should be specified according to temperature ranges anticipated during installation and in service.

(a) *Metal Piling*[1] (Below Water)
1. Preferred System: Primer, plasticized enamel, and cathodic protection.
2. Alternate System. Two coats Class (3) cold coating, and cathodic protection.

(b) *Metal Piling*[1] (Water line, Tidal zone)
1. & 2. Same as (a) Metal Piling with an anti-fouling compound or Monel shield covering tidal zone if barnacle attack is excessive.

(c) *Metal Piling* (Above Water)
1. Preferred System: Primer, plasticized enamel, one coat Class (4) cold coating.
2. Alternate System: One coat Class (3) cold coating; one coat Class (4) cold coating.

(d) *Metal Pipe* (Lined)
1. Preferred System: Primer, enamel (AWWA Spec.) white wash exterior and exposed interior ends.

(e) *Metal Pipe*[1] (Coated Below Water)
1. Preferred System: Primer, plasticized enamel, reenforcement, and/or wrapper and cathodic protection.
2. Alternate System: (Fresh water only) Two coats Class (3) cold coating, reenforcement and/or wrapper.

(f) *Metal Pipe* (Coated Below Ground)
1. Preferred System: Primer, plasticized enamel, reenforcement, and/or wrapper and cathodic protection.
2. Alternate System: (Where extremes of temperature are not encountered) Primer, unplasticized enamel, reenforcement, and/or wrapper and cathodic protection.
3. Alternate System (for line repairs): Two coats Class 3 cold coating, reenforcement and/or wrapper, and cathodic protection.

(g) *Metal Pipe and Metal Structures* (Coated Above Ground Outdoors)
1. Preferred System: Primer, enamel, and one coat Class 4 cold coating. (A good grade varnish base aluminum paint may be applied as topcoat to provide additional heat and light reflection.)
2. Alternate System: One coat Class 2 or Class 3 cold coating, one coat Class 4 cold coating. Varnish base aluminum paint may be applied here also.
3. Alternate System: Primer, two coats Class 4 cold coatings.

(h) *Metal Pipe and Metal Structures* (Coated Indoors)
1. Preferred System (light duty): Two coats Class 1 cold coating.
2. Preferred system (heavy duty): Two coats Class 2 cold coating.
3. Preferred System (chemical corrosive environment): g(1), g(2), or g(3).

(i) *Metal Pipe and Metal Structures* (Coated Indoors and with high atmospheric temperature, high humidity, and condensation)
1. Preferred System: Wash Primer, one coat Class 3 cold coating, one coat Class 4 cold coating.
2. Alternate System: Wash Primer, two coats Class 3 cold coating.
3. Alternate System: Wash Primer, two coats Class 4 cold coating.
4. Alternate System: Two coats Class 4 cold coating.

(Note: Wash Primer is a resin base non-bituminous composition which may be applied to clean damp surfaces successfully; it dries within a few minutes and provides a primed surface to which cold applied coal tar coatings will adhere tightly.)

(j) *Metal Structures* (Recoating Outdoors, Damp or Splash Zone)
Same as Systems under (i).

(k) *Metal Structures* (Coating Fire Retardant)
1. Preferred System: Primer, two coats Class 4 cold coating.

(q) *Insulation* (Coated)
1. Preferred System: One coat Class 3 cold coating, one coat Class 4 cold coating.

(r) *Moisture Vapor Barrier*
1. Preferred System: Pitch and felt membrane.
2. Alternate System: One coat Class 2 or Class 3 cold coating, one coat Class 4 cold coating.
3. Alternate System: (Masonry) concrete primer, one coat Class 3 cold coating, one coat Class 4 cold coating.

(s) *Protected Metal Corrugated Roofing and Siding and Accessories* (New Installations)
1. Preferred System: Protected metal.
2. Preferred System: (Marine, tropical, chemically corrosive environment, or combinations thereof) protected metal, followed by one sealcoat Class 4 cold coating.

(t) *Protected Metal, Roofing, and Siding* (Recoating)
1. Preferred System: Spot prime with primer, one coat Class 4 cold coating.

(u) *Metal Roofing and Siding, Old Galvanized, and/or Painted* (Recoating)
1. Preferred System: same as (t).
2. Alternate System: One coat Class 2 cold coating, one coat Class 4 cold coating.

In conclusion it must be stressed once again that no coating can give satisfactory protection if the surface is not properly cleaned, and if the coating is not properly applied. Proper design and planning also should be provided to eliminate types of surfaces which are more difficult to protect satisfactorily and economically. It is further suggested that a complete record of time, place, primers, coatings, rates of application, prevailing weather conditions, and the like be made wherever possible to provide accurate information by accumulation of data for successive or comparative installations of protective coating systems in different environments.

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End of Part 2 of 2 Parts

[1] Information will be presented in a later paper describing beneficial results obtained by using a barnacle resistant reenforced enamel top coating.

Any discussions of this article not published above will appear in the June, 1957 issue.

Design and Engineering Of Plastic Materials of Construction*

By O. H. FENNER and R. P. WHITTIER

Introduction

PLASTICS ARE FINDING an increasing growth in their application in the chemical and allied industries as project engineers become more and more aware of the many advantages to be gained through their use. Because corrosion is electrochemical in nature, many of the difficulties associated with the use of metals and alloys in corrosive environments are eliminated through the use of plastics. These difficulties include uniform, intergranular and galvanic attack, pitting, concentration cell corrosion and dezincification as well as contamination of the product. In their place, however, the physical properties of the particular plastic being employed are introduced, which may in themselves present paramount problems in design. The recommended procedure is to choose the plastic most resistant to the environment and then to apply engineering design to circumvent any inherent, unfavorable properties of the specific plastic. It is not the intention of this paper to reiterate the physical properties of the various plastics through any tabulation. This has been done very amply in many recent publications.[1,2,3,4,5,6,7,8]

The major deterrent to the application of plastics as materials of construction in the chemical and allied fields, is the scarcity of past performance and engineering design data that can serve as foci from which other uses become readily apparent. This has resulted in some reluctance on the part of design engineers to incorporate plastics in their plans for a particular project until they can be reasonably certain that the material will outlast its predecessor or normally used material of construction. Completion dates of the projects generally prohibit any lengthy tests of coupons in the particular service and, as a consequence, an acceptable plastic quite frequently is bypassed for an alloy with known past performance even though it may be uneconomical.

This paper presents experience of one major chemical company with the use of plastics equipment and a review of a company study of plastic pipe applications and future market potential. The activities and efforts of NACE Task Group T-5D-7 are summarized in hope that additional information will be funneled through this Committee for the mutual benefit of the chemical and allied industries.

Performance Data

Plastics have found a number of new applications as protective coatings of standard chemical processing equipment. Up until very recently, their use had been confined primarily to that of a temporary or emergency protective measure where they were considered as economically expendable materials. Lately, however, improvements in corrosion and solvent re-

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Abstract

Proper selection of plastics as materials of construction in the chemical and allied industries can result in tremendous savings in maintenance costs. Recommended procedure is to choose the plastic most resistant to the environment and then to apply engineering design to circumvent any inherent, unfavorable properties of the specific plastic. Applications of this technique are discussed and illustrated, with particular reference to the use of polyvinyl chloride, polystyrene, polyethylene, polyester glass fiber reinforced and phenolformaldehyde resins in the fabrication of chemical processing equipment and use as structural materials.

Good engineering design in the application of plastics is dependent largely upon the availability of past performance data. Included in this report are data on the maximum working pressure and tensile strength for plastic and metal pipe, maximum working temperature-pressure relationship for plastic and metal pipe and ratios of installed piping costs to pipe costs. 6.6.8

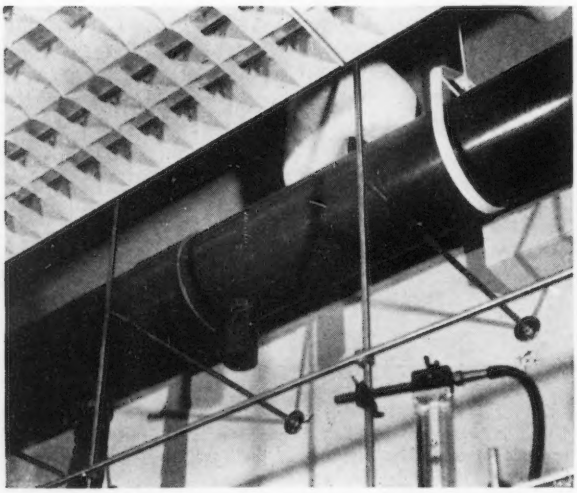

Figure 1—Rigid PVC used as duct work for fume exhaust system.

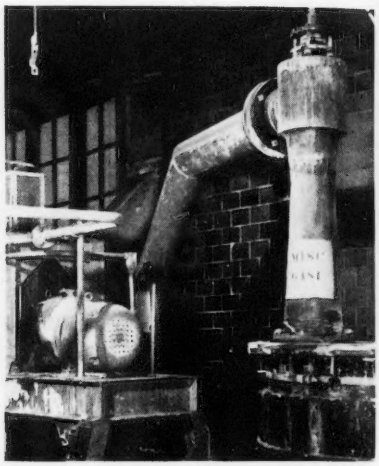

Figure 2—Six-inch PVC duct to a quencher.

sistance of these protective plastic coatings have given rise to their use as engineering materials for initial installations. The specific exposure dictates the preferential coating and various heat curing, air drying or catalytically cured phenolics, epoxies, furans, vinyls, alkyds, as well as vinylidine chloride copolymers and polyethylene have been used successfully for protection of new equipment. Recent coatings based on isocyanates in their formulation appear very promising and show extreme tenacity to the metal surface.

Lining of chemical apparatus with plastic materials is particularly appreciated where the two-fold problems of corrosion and abrasion are present. The mention of linings generally brings to mind sheeting material such as vinyls, acetates, butyrates, polyethylene, and acrylics. These are thermoplastic materials available in sheet form which can be readily fabricated and made to conform to intricate contours of pieces of apparatus, and which are lap-jointed and heat-sealed to complete fabrication. These materials are fastened to the inside walls of equipment by anchoring devices which are then coated over by sections of the parent plastic materials, lap-sealed to the main lining, or fastened by means of an appropriate adhesive. The adhesive used depends entirely upon the generic type of plastic employed and the surface to which the lining is to be fastened. The chapter on cementing in the SPI Plastic Engineering Handbook[1] covers the subject in complete detail. Major concern is the temperature at which the adhesive is no longer effective and lining sags away from the equipment.

Rigid thermoplastic pipe and duct work has found extensive application throughout Monsanto's plants. The major application has been in the use of rigid PVC to convey solutions containing hydrochloric acid in various concentrations. Off-gas vent lines and duct work of polystyrene or of polyvinylchloride carry fumes to exhaust systems from many tanks. As in the case of most thermoplastics, continuous application of temperatures above 165 F generally result in failure of the plastic through collapse.

One of the fastest growing applications of plastic materials for construction is the use of the reinforced thermoset resins. Their high temperature resistance and excellent acid and solvent resistance has made them invaluable. Glass fiber reinforced polyester or epoxy equipment has been put to good use in recent months since the original concern from wicking seems to have been overcome. These reinforced thermosetting resins are being safely used at temperatures up to 300-320 F, depending upon the resin employed.

Plastics as Engineering Materials of Construction

Uses of plastics as engineering materials of construction are illustrated in the following applications.

Case 1—Plastic Coated Rotary Dryer

Large scale production of an organic compound dictated its drying through the use of a rotary drum dryer. However, the presence of residual amounts of hydrochloric acid presented a problem in choice of a proper material. It was decided finally to utilize an existing 304 stainless steel drum by coating it with a phenolformaldehyde resin. Four coats of an alkaline catalyzed phenol-formaldehyde resin were baked on at 350-370 F. Off-gas ductwork and the product discharge chute were fabricated of sheet metal and coated with a room temperature curing modified phenolic resin. Shortly after the unit had been assembled and was in use, it became evident that the knockers on the outside of the drum, previously taken off, would have to be returned to prevent build-up of the wet cake. Rubber mallets were attached and immediately alleviated the problem. No spalling nor cracking was experienced by the phenolic coating. In spite of the fact that production cycles demanded an inlet air steam temperature of 275 F, this unit showed no signs of failure after 14 months service, during which time several million pounds of the product were dried successfully.

Case 2—Plastic Lined Chlorine Absorber

The steel cover and agitator of a cast iron tank, being used in the absorption of off-gas chlorine in

Figure 3—Worker in a plastics fabricator shop welding the inside of a 40-inch diameter PVC duct.[1]

lime water, were exhibiting prohibitive corrosion. Tests indicated the unsuitability of various alloys in this service because of the formation of the highly corrosive calcium hypochlorite. The cover was lined underneath with ¼-inch thick sheets of plasticized PVC. Since the final operating temperature approached 165 F just prior to the time that the contents of the tank are discharged to the sewer, and this was dangerously close to the upper temperature limit of the adhesive employed, supporting strips of steel were fastened on 1-foot centers and bolted through both the PVC sheet and the cover. These exposed steel strips then were coated with protecting strips of PVC. There has been some bulging in a few places but newer adhesives now available will correct this situation in future installations. The steel propeller blades of the agitator were built up with five layers of glass tape impregnated with a catalytically cured furane resin and then sanded to the desired contours to minimize wobbling; the steel shaft was protected by spirally wrapping polyethylene tape. The unit is still in service after 18 months.

Case 3—Polyester Glass Fiber Chute

Shortly after a glass fiber reinforced polyester chute was installed to convey dry powder to a weigh station, it was discovered that the flow of this dry powder through the chute was inducing a very critical static charge build-up on the outside wall. Because of the fact that inflammable liquids were being employed within the immediate vicinity the situation was even more serious. Accumulation of the static charge resulted in sparking, a particularly undesirable condition around flammable liquids or dry powder environments. This problem was remedied through prevention of this static charge build-up by adequate grounding. This was accomplished by the use of four 1-inch wide strips of copper placed lengthwise on the outside wall of the chute, around which a spiral of 12 gauge copper wire on 1-inch winding centers was wound the entire length of the chute. The entire copper network was grounded completely to the structural steel of the building.

Case 4—Rigid PVC Pipe

Figure 1 is an example of the use of rigid PVC

[1] Photo courtesy of St. Louis Metallizing Co.

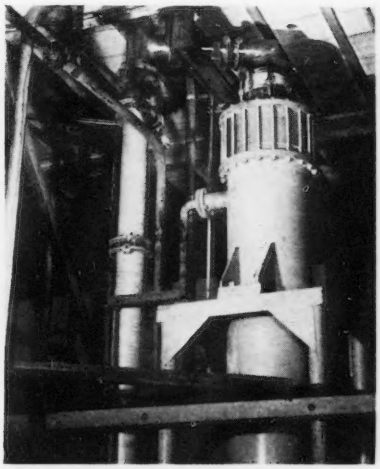

Figure 4—Portion of a vapor line from a glass-lined steel reactor.

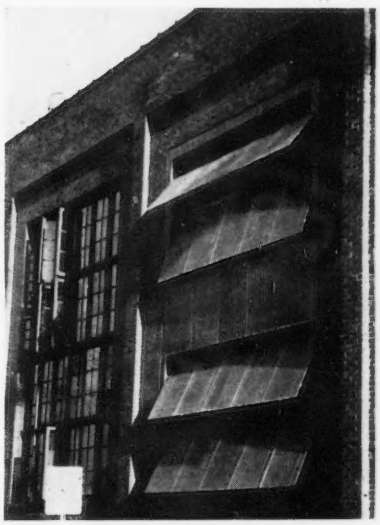

Figure 5—Polyester fiberglas windows (right) and older type windows.

as duct work for fume exhaust systems in the research laboratories. It illustrates the use of *cemented* sleeve coupling connections in the joining of the various horizontal lengths of pipe. The 3-inch vertical take-off nipples were welded into the duct prior to erection. It is interesting to note the light weight hanger used in supporting this 8-inch duct. These are spaced about 10 feet apart along the pipe as the only additional supports other than that furnished through contact with the exhaust blower. Type of support and spacing is dictated by the size of pipe and temperature to which the system is to be exposed.

Figure 2 shows another typical installation of plastics around a chemical plant. This is a 6-inch duct off of a quencher and is fabricated of PVC. It handles hydrochloric acid off-gases which are drawn through the jet into the scrubbing tank, both of which are of phenol-formaldehyde-asbestos composition.

Figure 3 shows a welder in the shop of a Saint Louis plastics fabricator welding inside of a 40-inch

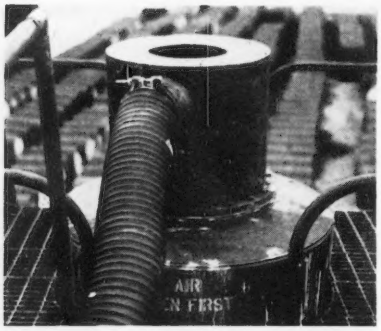

Figure 6—Polyester fiberglas hood for tank car.

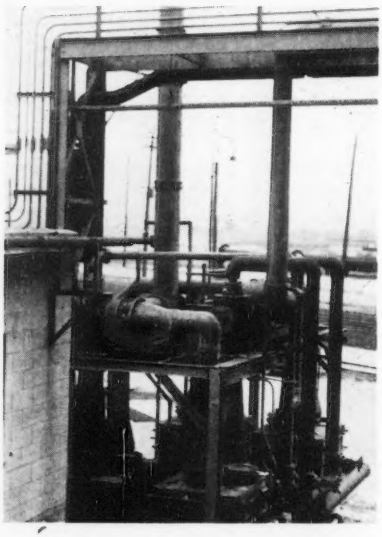

Figure 7—Eight-inch polyester fiberglas fume exhaust ductwork at tank car unloading spur.

diameter duct of PVC. It is shown to emphasize the fact that large structures are not unusual in fabrication of thermoplastic materials. The sheet used in this construction is preheated until it is flexible enough to be bent into the proper shape and then welded together.

These latter applications illustrate the use of welding in the fabrication of thermoplastic equipment. These are fillet welds and are made in a manner very similar to that experienced in the welding of metals, using a hot-gas torch and filler rod. A proficient welder produces a joint with an efficiency of at least 80 percent of the sheet strength.

Case 5—Plastic Armored Pyrex Pipe

In the manufacture of a particular organic compound, it was essential that a very low metal ion threshold be maintained. Since a relatively high temperature (130 C) was required and the use of alloys precluded, it was decided to use armored pyrex pipe. Figure 4 shows a portion of a vapor line off of a glass lined steel reactor. This joint application of glass pipe and plastics has resulted in a very important engineering material of construction. This armored glass pipe is made by wrapping a layer of epoxy impregnated glass tape about the pyrex pipe; curing of the epoxy in place results in a translucent, shatterproof pipe that can be hung in the conventional piping manner without channels and expanded metal guards.

Case 6—Carbon Filled Phenolic Cement

Weight of a heavy, inadequately supported, glass-lined steel vapor line introduced a severe stress and broke a nipple on the top of the carbon filled phenol-formaldehyde cast reflux condenser—also shown as a part of Figure 4. Serious down time appeared imminent while the unit was being replaced. The situation was reviewed and the broken nipple was cemented back into place with the use of modified phenol-formaldehyde cement. The flange connection was resupported by extending the stud bolts down to the steel shell. This arrangement placed the broken section under compression and eliminated the tension point on the nipple which had resulted in the original break. The unit has been in service for two years with no further difficulties.

Case 7—Polyester Fiberglas Windows

Severe corrosion to steel casements and deterioration of wooden frames raised the question of developing a window of fiberglas reinforced polyester construction for general use. Figure 5 shows a photograph of one type of window under test. The appearance of the section it is replacing can be seen further along the building.

Case 8—Polyester Fiberglas Fume Duct

Figure 6 shows a polyester fiberglas hood for off gases during loading of a tank car of phosphorous oxy-chloride at 120-140 F; the use of the light weight hood reduced labor costs since one man can handle an entire operation which formerly required two.

The rubber covered spiral wire reinforced flexible coupling shown connects to the 8-inch polyester fiberglas ductwork shown in Figure 7. This passes the gas to drowning jets of Haveg; residual gases are finally vented through another polyester stack.

Pipe Study

In watching these applications and observing the rapid advances made by the plastics as legitimate materials of construction from the viewpoint of both supplier and user, the authors' company some time ago concluded that an extensive review of the current situation was warranted. One phase, that related to plastic pipe, has been completed and published;[8] a limited number of preprints of the study are available. A frank appraisal of the strengths and weaknesses of plastic pipe will do much to promote its long-term acceptance for industrial, commercial, or residential usage. An analysis now of the approach taken on the problem, illustration of several of the more interesting comparisons that were developed, and some of the conclusions that were gained from a study of the data is pertinent to corrosion engineers.

Much research has been devoted to the development of a plastic pipe that is sound from a technical and economic aspect, as a review of source publica-

tions will reveal. There is, however, no available comprehensive survey of the over-all market for plastic pipe per se. For that reason it was decided to examine the broad competitive position of all types of plastics. The major kinds (polyethylene, polyvinyl chloride, styrene copolymer, cellulose acetate butyrate, and polyester) are shown in Table 1 which tabulates the 1955 production in millions of pounds as well as their major applications. Of the more than 40 million pounds which were used, nearly 25 percent went into industrial piping, despite the fact that only one of these types had been commercially available five years previously.

It is quite evident to persons familiar with the physical properties of the presently available plastics that there is no one all-purpose plastic. Each generic type has its own special virtues and limitations. It appears reasonable to suppose that this picture will not change within the immediate future and that several different types will be required for specific needs as is common practice with the metals and alloys.

Advantages of plastic pipe compared to metal pipe are as follows:

1. Better resistance to corrosion—no rusting.
2. Greater water carrying capacity—does not build up solids deposits to resist flow.
3. Light in weight and easy to install—from $\frac{1}{5}$ to $\frac{1}{8}$ the weight of metal.
4. Not affected by electrolysis.

Disadvantages of plastic pipe compared to metal pipe are as follows:

1. Low working pressures for thermoplastic types.
2. Low working temperatures for thermoplastic types.
3. Flexible types have poor abrasion resistance.
4. Flexible types require essential continuous support to ensure against sagging.

To clearly illustrate the operating limitations imposed upon the plastics in comparison with commonly employed metal pipe, the recommended working pressures at a constant temperature of 75 F are tabulated in Table 2. Two inch pipe was arbitrarily selected for this presentation. The carbon steel, polyethylene, galvanized iron, cellulose acetate butyrate, polystyrene copolymer, polyvinyl chloride and brass are schedule 40, while the copper "L" and polyester are schedule 20. It might be noted that the plastic has a disproportionate increase in strength as the diameter is reduced and by the same token, the larger diameter pipe has a considerably lower working pressure.

The relationship of the maximum working pressure to the maximum recommended operating temperature is much more critical with plastic than with metal. This is shown by comparing Table 2 with Table 3 where steel is reduced from 850 to 500 psi or 350 psi net loss over a temperature range of 575 degrees F, while the working pressure of PVC is lowered 101 psi in 105 degrees F elevation.

It is obvious that the thermoplastic materials will not perform satisfactorily at extreme temperatures; it is equally logical to anticipate that with suitable formulations and possibly a reinforcing web, liquids can be handled conveniently at temperatures of 250 to 300 degrees F within a very few years.

Performance is one criteria by which a material is judged. Cost is another factor of paramount importance. Pipe installation costs approximately as much as the initial price of the pipe itself according to Table 4, varying to some extent on the number of fittings required. For this derivation eight fittings including ells, tees, and couplings per 100 foot of pipe were estimated for all types—this represents roughly

TABLE 1—Plastic Pipe and Its Uses

Kind of Plastic	Type	Estimated 1955 Sales (Millions of Pounds)	Use
Polyethylene	Thermoplastic	30	Chiefly Oil Well Water Systems
Polyvinyl Chloride	Thermoplastic	3	Oil Lines and Industrial
Styrene Copolymer	Thermoplastic	4.5	Oil Lines and Industrial
Cellulose Acetate Butyrate	Thermoplastic	4.5	Gas and Oil Lines, Industrial
Polyester Glass	Thermosetting	Not Available	Gas and Oil Lines, Industrial

TABLE 2—Maximum Working Pressure and Tensile Strength of Plastic and Metal Pipe (Two Inch Pipe)

Material	Allowable Working Pressure at 75 F in psi	Maximum Tensile Strength in psi
Carbon Steel	850	48,000
Polyethylene	75	2,500
Galvanized Iron	850	48,000
Cellulose Acetate Butyrate	100	6,700
Polystyrene Copolymer	165	6,000
Polyvinyl Chloride	156	9,000
Copper "L"	300	35,000
Polyester	600	41,000
Brass	400	40,000

TABLE 3—Maximum Working Temperature-Pressure Relationship for Plastic and Metal Pipe (Two Inch Pipe)

Material	Maximum Working Temp. in Degrees F	Allowable Pressure (psi)
Carbon Steel	650	500
Polyethylene	160	25
Galvanized Iron	650	500
Cellulose Acetate Butyrate	150	65
Polystyrene Copolymer	170	60
Polyvinyl Chloride	180	55
Copper "L"	406	198
Polyester	275	120
Brass	406	394

TABLE 4—Ratios of Installed Piping Costs to Pipe Costs* (1954 Prices)

Pipe	Pipe Cost $/Ft.	Ratio Installed Pipe Cost (P-Factor)	Estimated Cost 100 Ft. Pipe Installed
Plastic:			
Polyethylene (General Purpose)	.20	2.4	$48.00
Cellulose Acetate Butyrate	.22	2.5	55.00
Polystyrene Copolymer	.39	2.0	78.00
Polyvinyl Chloride	.46	2.0	92.00
Metal:			
Carbon Steel	.17	2.8	47.60
Galvanized Iron	.20	2.8	56.00
Copper "L"	.41	2.2	90.20

* 1 inch Pipe.

10 percent of the cost of a standard job but considerably more for plastic fittings. In evaluating this situation, polyethylene is competitive with steel while all plastic types are highly competitive if superior corrosion resistance is required, other factors being acceptable. The development of methods specifically designed for joining plastic pipe will drastically improve the installed cost picture. The solvent welding technique employed to some extent with the cellulose acetate butyrate and the heat welding of polyvinyl chloride are indicative of what may be expected. In addition to recognizing the need for better materials and lower installed costs through improved techniques, it is concluded that plastic pipe will gain universal acceptance only when the quality is standardized and when dimensional standards are achieved. Activity here has been through the SPI which is promoting standardization through committee work and through outside research programs such as that sponsored at the Battelle Institute for the determination of industrial specifications for the safe working temperatures and pressures of plastic pipe.

Another factor that hampers the acceptance of plastics is the lack of engineering test information on pipe performances. This has been correlated by the findings of the NACE Task Committee T-5D-7. This committee has solicited information relevant to engineering design data on plastics from the chemical industries. Their findings read in part, "The prime desire (of engineers) appears to be need for greater dissemination of actual experiences with plastics which might be used as yardsticks to estimate possible performances of these materials in other environments." It is heartening to read the objectives of this committee, to study the results of their questionnaires and to discover that the authors are so much in agreement with the recommendations for future action to overcome problems. The *development* and *distribution* of technical data, the *experimental application* of materials and shapes, and the *cross-fertilization of ideas* at these conferences are all elemental features of the broad effort that will advance the proper use of plastics as a material of construction.

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Any discussions of this article not published above will appear in the June, 1957 issue.

Naphthenic Acid Corrosion – An Old Enemy Of the Petroleum Industry*

By W. A. DERUNGS

Introduction

NAPHTHENIC ACID corrosion was observed for the first time in the 1920's when certain crudes from Roumania, Russia (Baku Region), South America and California were distilled. As early as 1930, during the 11th annual meeting of the API, Blount[1] stated that the crude oils contained three distinct sources of corrosion in distilling equipment:

1. Magnesium chloride
2. Sulfur
3. Naphthenic acids

In the presence of water, magnesium chloride is hydrolyzed during the distilling process. It then develops aqueous hydrochloric acid which, below its dew point, is very corrosive to nearly all common metals and alloys.

In contrast to hydrochloric acid, hydrogen sulfide, which may be developed from sulfur-containing crudes, becomes most active at higher temperatures without the necessity of water being present. This behavior holds true also for the naphthenic acids which are present in several crude oils.

Because nearly all crudes containing naphthenic acids also contain material quantities of sulfur compounds which under similar conditions can give rise to severe corrosion of refinery equipment, it is obvious that a differentiation between sulfur corrosion and naphthenic acid corrosion is difficult. It is reasonable to assume that at least part of the corrosion generally attributed to naphthenic acids is due to the action of sulfur, and vice versa. However, by observing the corrosion phenomena on steel, it is possible to make a practical differentiation between naphthenic acid and sulfur corrosion. Streams high in naphthenic acid content generally produce very characteristic, sharp-edged holes or—in cases where the stream is of high velocity—sharp-edged streamlined grooves. Such typical forms of attack have never been observed when processing crudes free from naphthenic acids. Also, in the presence of naphthenic acids, the critical temperature at which severe corrosion may occur is considerably lower than in the case where only sulfur is present.

In the early 1930's corrosion by sulfur and naphthenic acids at high temperature was an extremely serious problem. When mild steel furnace tubes were used, tube bursts once a week were common. Cast steel return bends had a service life of as short as 80 days and transfer lines of mild steel had to be replaced within 100 days to one year. Serious corrosion of mild steel heat exchangers was another source of trouble.

In the course of time it was found that steel could be made resistant to sulfur by alloying it with chromium. Addition of 5 percent Cr makes steel fairly resistant, and with 12 percent Cr-steel very satisfactory results are obtained under practically all circumstances.

Where naphthenic acid corrosion is involved the remedy is not so simple as that. Not enough facts

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Abstract

The term "naphthenic acids" is a collective name for organic acids present in various crudes. It has been proved that while minor quantities of other organic acids are included, the main acids from naphthenic base crudes are saturated ring structures containing acid groups.

The circumstances under which naphthenic acid corrosion occurs are analogous to those of sulfur corrosion. A practical differentiation between naphthenic acid and sulfur corrosion is possible on the basis of different corrosion phenomena. It would appear that the rate of naphthenic acid corrosion is dependent on the concentration of the naphthenic acids in the oil, operating temperature, fluid velocity and activity of the naphthenic acids. Of these factors fluid velocity seems to be the most important. Unfortunately the critical velocity values below which the corrosion rates become negligible are not yet known.

Data are given to show the relationship between temperature and corrosion rates at selected locations in a high vacuum column of a distilling plant. Corrosion of mild steel by naphthenic acids becomes apparent at operating temperatures in excess of 220 C (430 F) with a maximum at approximately 280 C (540 F). Above 400 C no evidence of this type of corrosion has ever been found.

Naphthenic acid corrosion can be counteracted by removal or neutralization of the naphthenic acids by modifying fluid velocity conditions where possible and by proper selection of the constructional materials. Some hints on the suitability of various materials of construction are given. 4.4.2

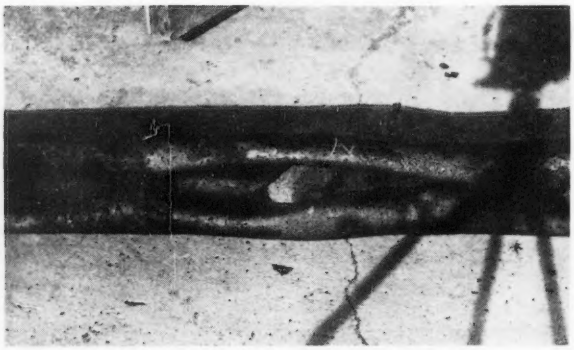


Figure 1—Failure of mild steel furnace tube. Tube was from a high vacuum plant which had operated for 163 days on sweet crude and 259 days on naphthenic crude. Operating temperature was 300 C.

TABLE 1—Type Distribution of Oils Obtained from Naphthenic Acids from a Luboil Range

TYPE	Mol Weights of Oil Fractions		
	281	384	470
Saturates	68	58	45
Monoaromatics[1]	15	18	16
Diaromatics[1]	6	12	23
Benzothiophenes[1]	5	8	
Resins	6	4	16

[1] Monoaromatics are to a large extent condensed with five or six-membered naphthene rings while only a small proportion of diaromatics and benzothiophenes is condensed in this way.

are known to predict the occurrence of naphthenic acid corrosion, whereas satisfactory protection against it is in general expensive and often complicated. Therefore, certain risks are taken, often resulting in unanticipated, sudden failures.

Figure 1 represents a mild steel furnace tube which not so long ago had failed in a furnace of a high vacuum plant after 422 days of operation. It had operated on sweet crude for 163 days and on crudes containing naphthenic acid for 259 days at an oil temperature of approximately 300 C (570 F). On the other hand expensive materials sometimes have been used to safeguard operation when it was found later that less valuable materials would have performed just as well.

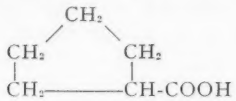
Considering all these circumstances, a more extensive investigation into naphthenic acid corrosion appears justified.

Data on Commercially Available Naphthenic Acids

A number of grades of naphthenic acids are marketed for various purposes. The grades are distinguished by their acid values, as, for example, the "230 Grade" and "170 Grade" acids, having a minimum acid value of 230 and 170 mg KOH/g respectively. The higher acid value material is obtained from kerosene and light gas oil, the lower acid value material from heavy gas oil. The average molecular weight is in the range of 200-300. The flash points may vary from 138-150 C (280-300 F). Specific gravity is near unity. Naphthenic acids are barely soluble in water, but readily soluble in most organic solvents, particularly hydrocarbons.

Chemical Constitution of Naphthenic Acids

"Naphthenic acids" is a collective name for organic acids present in various crude oils. The name is derived from the fact that acidity was first observed in naphthenic base crudes (Russian crude oils of the Baku region). Although there are minor amounts of other organic acids included, it was confirmed later that the main acids from naphthenic base crudes are actually naphthenic in their character (i.e., acids with a saturated ring structure such as given below):



Boiling point = 55-64 C (131-147 F) at 20 mm Hg
Mol. weight = 114

The molecular weights of the naphthenic acids extend over the extremes from high to low but the bulk of the naphthenic acids in crude oils generally is found in the gas oil and light lubricating oil fractions.

The Royal Dutch/Shell Laboratory at Amsterdam recently investigated the naphthenic acids from a luboil range making use of improved methods for the isolation and fractionation of the acids, followed by complete conversion of these acids into neutral compounds ($COOH \rightarrow CH_3$). Analysis of these neutral compounds by means of the methods currently applied in oil constitution work revealed that these compounds closely resembled the neutral distillate fraction with a similar molecular weight and from the same crude oil. The only difference observed was the absence of polyaromatics (except diaromatics). Naphthenic acids therefore are based upon saturates, monoaromatics, diaromatics and sulphur compounds. Table 1 shows the type distribution of the oils obtained from the corresponding acids.

Characteristics of Naphthenic Acid Corrosion

Locations

Naphthenic acid corrosion is encountered mainly in crude distilling plants and in high vacuum distilling plants processing certain sour crudes or derivatives thereof. Type of equipment chiefly subject to this corrosion includes hot oil centrifugal pumps, furnaces (especially return bends and tube inlet ends), transfer lines, feed and reflux sections of columns, heat exchangers, condensers and objects which hinder a smooth stream (e.g., thermowells, bolts and rough welding seams).

Naphthenic acid corrosion has not been found to be of much importance in cracking plants, nor in the re-processing of cracked products. However, certain acids (i.e., carbon dioxide, light fatty and unsaturated acids) are split off from naphthenic acids in cracking plants in addition to hydrocarbons. These light acids may be corrosive primarily at low temperatures, especially so if water is present. This is in direct contrast to the high temperature corrosion attributable to naphthenic acids.

Acidity of Feedstock

In addition to sulfur compounds it is probable that all sour crudes also contain a certain amount of naphthenic acids. These acids become important as a corrosion factor only if the acid value of the feed-

Figure 2—Naphthenic acid corrosion on mild steel furnace tube inlet end.

stock is at least 0.5 mg KOH/g. It might be pointed out that acid values up to 10 mg KOH/g may occur.

Appearances of Naphthenic Acid Corrosion

The appearances of naphthenic acid corrosion are generally highly characteristic, varying with increase in stream velocity from sharp-edged, crater-like holes to sharp-edged streamlined grooves (see Figures 2, 3 and 4). The corrosion products—at least those from iron and copper and their common alloys—are easily dissolved in moving hot oil and washed off, leaving no scale behind. These facts explain the characteristic appearance of the attacked metal. One is inclined to think of erosion, whereas actually velocity corrosion has taken place. Evidence for this velocity corrosion is found in the fact that acid-free, cracked or neutralized oil does not give any such wear, and also that a soft material like aluminum, which does not react with naphthenic acids, remains practically unaffected.

State of Aggregation of the Active Naphthenic Acids

Whether the naphthenic acids are more corrosive in the liquid than in the vapor phase, or whether they are corrosive only in the one or the other state respectively, is difficult to say. A definite pronouncement is all the more difficult inasmuch as the naphthenic acids present in distilling plants are only a minor part of the total product. They are dissolved in fractions of oil showing the same boiling range as the naphthenic acids. As a further circumstance the true boiling range of the naphthenic acids may be shifted by other components. Moreover, corrosion inhibitors and promoters may play a role.

Describing his experience in the refining of California crudes, Tandy[2] states that the naphthenic acids are most active at their boiling points but that most severe corrosion generally occurs on condensation, whereas in the vapor state practically no corrosion takes place. Laboratory tests conducted by the author's company have confirmed Tandy's findings. These findings, however, are in striking conflict with plant experience which indicates that where a vapor phase exists, corrosion is invariably more severe than in a pure liquid phase. This contradiction possibly

Figure 3—Naphthenic acid corrosion in feed section of a high vacuum column.

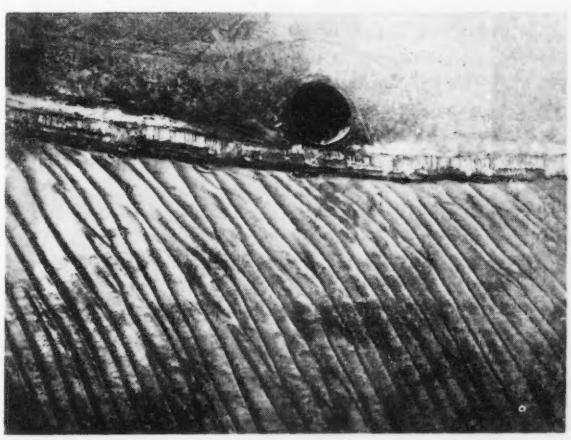


Figure 4—Additional view of naphthenic acid corrosion in feed section of a high vacuum column.

can be explained by the fact that the liquid velocity is considerably increased if vaporization occurs.

Influence of Temperature

In considering the influence of temperature on corrosion a distinction must be made between actual metal wall temperature and product temperature. As the metal wall temperature generally is not known reference will be made instead to the oil temperature. It is realized that the actual wall temperature may

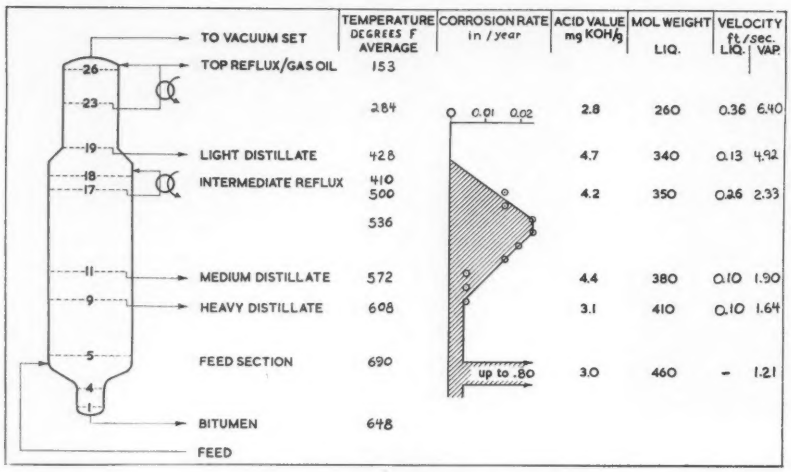


Figure 5—Corrosion and operating data of a high vacuum column processing a reduced crude.

be either higher (e.g., furnace tube) or lower (e.g., transfer line) than oil temperature. Apart from practical considerations the use of the product temperature seems justified, inasmuch as the activity of the naphthenic acids themselves depends greatly on the temperature.

Considering for the time being the corrosion behavior of unalloyed steel only, the minimum temperature below which oil in the absence of water is not at all corrosive is 220 C (430 F). At higher temperatures naphthenic acid corrosion becomes evident, the rate of corrosion gradually increasing with the temperature. Maximum corrosion often occurs at a temperature around 270-280 C (520-535 F). At a temperature of 350 C (660 F) upwards the corrosion rate again increases rapidly, being due for the most part to the action of sulfur. Above 400 C (750 F) no evidence of naphthenic acid corrosion has ever been found. This relationship between corrosion rate and temperature may be seen in the discussion that follows.

In some distilling plants processing reduced crude, corrosion in the hottest furnace tubes and transfer lines was about 6 mm per year (.24 in/year). Product temperature in such cases was about 375 C (710 F). When the transfer temperature was lowered to 350 C (660 F) practically no further corrosion occurred.

Later it became necessary to modify the same plants to work up total crude oil. Owing to this modification the transfer temperature was further reduced to about 270 C (520 F). This drop in temperature caused corrosion rates again to become of the order of 10 mm/year (.4 in/year). In consequence of this, further restrictions on temperature (and load) had to be stipulated.

In fractionating columns of high vacuum distilling plants processing a reduced crude oil a maximum corrosion rate of approximately 0.6 mm/year (.024 in/year) at around 280 C (535 F) has been measured (see Figure 5). Another maximum of corrosion, being up to 20 mm/year (.8 in/year), could be found in the inlets of the columns where evaporation took place at around 380 C (715 F). Similar high corrosion rates have been found in furnaces (especially in return bends and tube inlet ends) and transfer lines (especially in bends), although without distinctly showing a separate maximum corrosion rate dependent on temperature. Apart from the action by sulfur these extremely high corrosion rates undoubtedly are due in part to the presence of napththenic acids at places where high fluid velocity exists: Fluid velocity (vapor-liquid mixture consisting chiefly of vapor) has been calculated to reach an average of up to 185 m/sec (600 ft/sec) at the furnace outlet.

What is the reason for the decrease in naphthenic acid corrosion after a temperature of 280 C (535 F) is exceeded? Could this be due to the fact that above this temperature naphthenic acids decompose?

As already stated above, naphthenic acid corrosion in cracking plants is of little importance. This is due primarily to the fact that the liquid velocity in the furnace is relatively low and that in the vapor phase the naphthenic acids decompose. The exact temperature at which decomposition sets in is not known; it must, however, be below 485 C (905 F), the furnace outlet temperature.

In the distilling plants for straight-run distillation, i.e., at temperatures up to 320 C (610 F), the naphthenic acids are definitely not decomposed. A naphthenic acid balance made at a high vacuum distilling plant proved that no marked decomposition of the naphthenic acids had taken place. The furnace outlet temperature had been 400 C (750 F) in this case. It also has been found that the acid value of asphalt obtained from a vacuum plant increases sharply when the transfer temperature is reduced from, say, 420 C (790 F) to 380 C (715 F) while still producing the same grade of asphalt.

The above facts lead to the conclusion that naphthenic acids present in refining equipment are decomposed in a temperature range somewhere between 400-485 C (750-905 F), and more probably at the lower limit. Therefore the occurrence of a maximum corrosion rate at 280 C (535 F) in vacuum columns cannot be ascribed to decomposition of the naphthenic acids above this temperature.

It is known that corrosion by naphthenic acids is much dependent on fluid velocity. In order to find out whether different velocities play an important role in fractionating columns of high vacuum distilling plants, the internal load of a column processing reduced crude was calculated. The relative liquid and vapor velocities obtained are shown in Figure 5. As relative velocities the liquid velocity through the downcomers and the vapor velocity through the whole column cross section were calculated. From this calculation it appears that in the case under consideration the velocity effect is rather small and

by no means gives an explanation for the extraordinary corrosion phenomenon in the column.

The acid values and molecular weights of the various streams were determined as shown in Figure 5. It can be seen that the acid value (a.v.) in the column increases from the feed (a.v. = 3.0) upwards to the light distillate stream (a.v. = 4.7). Up to a certain degree the increase of the acid value is in correlation with the increase of corrosion. However, corrosion is most severe immediately below the intermediate reflux section, where the acid value (a.v. = 4.2) is even somewhat lower than at the draw-off of the medium distillate (a.v. = 4.4) and at the draw-off of the light distillate (a.v. = 4.7). An explanation of this phenomenon can be found when taking the molecular weights or more exactly the activities of the various naphthenic acids into account. It is quite clear that the molecular weights will decrease in the upwards direction of the column. With a decrease of the molecular weights the activity of the naphthenic acids will increase, since the smaller the molecules the greater becomes their activity. Furthermore, if it is taken for granted that these smaller molecules are more active in liquid than in vapor phase and in liquid phase more active near the boiling point, corrosion will necessarily be at a maximum where these most active molecules are condensing or boiling respectively. Such conditions obviously occur below the intermediate reflux section.

It is true that at the draw-off of the light distillate even more active naphthenic acids may exist. For that reason at least the same high corrosion rate as below the intermediate reflux section might be expected. This is not the case, because the operating temperature is considerably lower.

Condensing or boiling point of the most active naphthenic acids will depend also on the constitution of these naphthenic acids, which constitution will vary somewhat with various crudes.

There is little chance of accumulation of naphthenic acids at condensing or boiling conditions in furnaces and transfer lines. This may explain why here generally no maximum corrosion rate dependent on an intermediate temperature between 220-400 C (430-750 F) is found.

The above explanation is a hypothesis which will have to be confirmed by experiments. For this purpose it is recommended that corrosion tests be made with various fractions at various temperatures.

Influence of Velocity

Fluid velocity is of preponderant influence on the rate of corrosion. Often very severe corrosion is found at places where a high turbulent stream—possibly combined with impact—exists, whereas at neighboring places free from intensive turbulence only little corrosion occurs. This fact is most clearly demonstrated in return bends and tube inlet ends of furnaces, and in bends of transfer lines. Another example is the difference in corrosion experienced in the hottest furnace tubes of a distilling plant processing a certain crude, where it was found that at a temperature of 270 C (520 F) the corrosion rate remained low with a load of 40 tons/day sq inch cross section but became high with a load of 70 t or more. Unfortunately, the critical absolute velocity values (varying with temperature) below which the corrosion rates remain low are not yet known.

Volatility of a product, operating pressure, and injection of steam will have a considerable influence on the fluid velocity.

Volatility: The lighter the intake material, the greater the amount of vaporization. Since an increase in vapor volume means a greater velocity, a higher rate of corrosion must be expected.

Pressure: When distilling in vacuum the velocities will increase directly owing to the increased volume and indirectly owing to the increased vaporization.

Steam: Injection of steam (or presence of water in the feed) again will increase the vapor volume and consequently the fluid velocity and rate of corrosion.

Protection Against Naphthenic Acid Corrosion

Reduction of Free Naphthenic Acid Content

There are two principal ways to reduce the free naphthenic acid content of crude oils or derivatives thereof:

1. **Removal:** Active naphthenic acids may be removed by pretopping at relatively low temperature so that little corrosion will occur.
2. **Neutralization:** Naphthenic acids present in kerosene and gas oil fractions can be removed by extraction with aqueous caustic soda. Acids of higher molecular weight present in lubricating oil stocks cannot be removed by this method, owing to severe emulsification. In order, therefore, to obtain neutral distillates, the crude lubricating oil feedstock is neutralized with either lime or caustic soda during high vacuum distillation. The calcium or sodium naphthenates are drawn off as a side stream in the column above the feed inlet in order to prevent increase of the ash content of the bottom product.

Proper Selection of Materials of Construction

Unalloyed steel: Mild steel is not attacked by naphthenic acid-containing oils below a temperature of 220 C (430 F). In the temperature range of, say, 220-400 C (430-750 F) mild steel may be attacked up to 20 mm/year (.8 in/year), depending on operating conditions. Extra low carbon steel (e.g., Armco iron) has proved to be somewhat more resistant than normal mild steel.

Cast iron: Cast iron has been found to be up to about 15 times more resistant than mild steel. It may be useful for internal parts of column.

Alloyed cast irons: Ni-Resist (15 percent Ni, 6 percent Cu, 2 percent Cr, rest Fe) and other alloyed cast irons have no improved corrosion resistance over unalloyed cast iron.

Low alloy steel: Under conditions of increased fluid velocity 5 Cr-½ Mo steel may be up to 15 times as resistant as mild steel. Except perhaps for furnace and heat exchanger parts the usefulness of this material is doubtful, inasmuch as it is often very irregularly attacked, chiefly in the form of pitting.

Stainless steel: 12 percent Cr-steel (AISI 405, 410) often appears to be even less resistant than mild steel and, therefore, should not be used in the presence of naphthenic acids. Stainless steel of the type 18 Cr-8 Ni (AISI 304, 321, 347) is often quite resistant under conditions of low fluid velocity such as exist in certain parts of columns. It sometimes is subject, however, to severe pitting and therefore is not very reliable. On the other hand, stainless steel of the type 18 Cr-8 Ni-3 Mo (AISI 316) has proved to be very resistant under all circumstances. Mo-contents of 1½ percent, however, are quite sufficient for naphthenic acids. The same applies to the 25 Cr-20 Ni (AISI 310) and 25 Cr-12 Ni (AISI 309) types of stainless steel.

High nickel alloys: With the exception of copper-containing nickel alloys (e.g., Monel = 66 percent Ni, 30 percent Cu + other elements) these are all highly resistant. However, these materials (e.g., Inconel = 76 percent Ni, 15 percent Cr, rest Fe and Hastelloy B = 65 percent Ni, 30 percent Mo, 5 percent Fe) are much more expensive than AISI 316, and have little more advantage over the latter.

Copper and copper alloys: These materials are not suitable, being attacked at 150 C (300 F).

Aluminum and Aluminum Alloys: Aluminum has proved to be very resistant under all conditions. Unfortunately, its use thus far has been restricted by its mechanical and welding properties. Copper-containing aluminum alloys (e.g., Duralumin with 5 percent Cu) are not suitable.

Summary

Naphthenic acid corrosion has been and still is a problem in the petroleum industry.

The term "naphthenic acids" is a collective name for organic acids present in various crudes. It has been proved that, although there are minor quantities of other organic acids included, the main acids from naphthenic base crudes are saturated ring structures containing acid groups.

The circumstances under which naphthenic acid corrosion occurs are analogous to those of sulfur corrosion. A practical differentiation between naphthenic acid and sulfur corrosion is possible on the basis of different corrosion phenomena.

It appears that the rate of naphthenic acid corrosion is dependent on the concentration of the naphthenic acids in the oil, operating temperature, fluid velocity and activity of the naphthenic acids.

Naphthenic acid corrosion is counteracted by removal or neutralization of the naphthenic acids, by modifying fluid velocity conditions, where possible, and by proper selection of the constructional materials. Some hints on the suitability of various materials of construction are given.

References

1. *API Proceedings*, **11**, No. 75 (1930), Sect. 3, p. 102.
2. E. H. Tandy, Inspection of Petroleum Refinery Equipment. *Corrosion*, **10**, No. 5, 161 (1954) May.

DISCUSSION

Comment by E. H. Tandy, Standard Oil Company of California, El Segundo, Calif.:

Mr. Derungs is to be congratulated for his fine paper on naphthenic acid corrosion. We agree that naphthenic acid corrosion is severe at points of high velocity and turbulence in furnace tubes and headers, transfer lines, etc. Corrosion in the flash zone or feed section of the fractionating column is the result of hydrogen sulfide, naphthenic acid and high velocity. This combination is particularly severe because no scale is formed to protect the metal surface. The appearance of the shell in Figures 3 and 4 suggests that one of the major factors is the condensation on the shell of heavy naphthenic acids which then run down in rivulets corroding the grooves. The rivulets in Figure 3 around the transfer inlet are displaced because of the circular sweep of the vapors in that area. Once the naphthenic acids have reached the top stripping tray they become diluted by the oil on the tray thus causing the abrupt drop in corrosion below the flash zone.

It seems to be characteristic of naphthenic acids that they have rather sharp dew points. As Mr. Derungs suggests, they probably form azeotropic mixtures with the hydrocarbons which are high in acid content thus causing severe corrosion to any surface on which they condense. This theory can also be applied to the area of the column under the intermediate reflux section. Here, as the vapors are cooling down, the naphthenic acid-oil mixtures condense on the shell causing the corrosion. Once this mixture runs down onto the tray it becomes diluted by the oil on the tray and is much less corrosive. Usually the shell does not have the striated appearance found in the flash zone because the shell is wetted with a continuous sheet of condensate. However, if there are any projections or unused nozzles in this area the shell will be grooved under them from the rivulet of acid-oil that collects there and then runs down the shell.

This phenomena of high corrosion at the dew point also is found in fractionating column condensing equipment where the top tray temperature is high enough for the naphthenic acid vapors to go out overhead. The condensing system often will have small zones of high corrosion when compared with the areas immediately above and below. The corroded area is usually in the zone where condensation first begins. The first condensate is the acid-oil mixture which quickly becomes diluted as it falls further in the system.

Corrosion of Type 347 Stainless Steel and 1100 Aluminum In Strong Nitric and Mixed Nitric-Sulfuric Acids*

By CHARLES P. DILLON

Introduction

IT IS NECESSARY to employ mixed nitric-sulfuric acid in certain phases of the production of synthetic organic chemicals. This involves the transportation and storage of the acid.

It is known that additions of sulfuric acid to concentrated nitric acid diminish the activity of any water present, and that steel vessels can successfully handle some mixed acids.[1] Interstate Commerce Commission regulations[2] permit the use of steel shipping containers for nitric acid when the composition of the acid falls within the following ranges:

1. Up to 10 percent water, 10 percent sulfuric acid minimum.
2. Up to 15 percent water, 15 percent sulfuric acid minimum.
3. Up to 20 percent water, 20 percent sulfuric acid minimum.
4. Up to 38 percent water, 62 percent sulfuric acid minimum.

A commercially available mixed acid of the composition 85 percent nitric, 13.5 percent sulfuric, 1.5 percent water appeared to offer maximum economy both in total acidity and in the use of steel equipment.

Attempts to store this mixed acid in a steel tank, from which it could be pumped into the process, resulted in severe corrosion and rapid failure. Subsequently, a steel tank clad internally with Type 347 stainless steel was employed. It likewise failed within 12 months service. The attack was characterized by severe corrosion of the top and walls, with slight attack on the bottom under copious coarse crystalline deposits of chromium, nickel and iron sulfates.

The first suspected corrosive agents were chloride ions and the dissolved metal salts. The former have been known to cause pitting attack in mixed acids, while the latter cause high rates of attack in conventional boiling 65 percent nitric acid tests. A laboratory investigation was undertaken to investigate the cause of the failure of the Type 347-clad tank. It was later extended to study the characteristics of corrosion of both Type 347 stainless and 1100 aluminum in various mixtures of nitric and sulfuric acid. The nominal composition of the alloys is given in Table 1.

Procedures

Corrosion coupons 1 inch x 1½ inches x 0.125 inch were fabricated from Type 347 stainless steel and from 1100 aluminum. The specimens were finished to 120 grit, cleaned, and weighed to the nearest tenth of a milligram.

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Abstract

Rapid corrosion of a Type 347 stainless steel-clad tank was encountered in the storage of a mixed acid of the composition 85 percent nitric acid-13.5 percent sulfuric acid-1.5 percent water. A laboratory investigation of the mechanisms of attack in this and similar acids shows severe vapor-phase corrosion of austenitic stainless steel above 95 percent total acidity. The attack was unaffected by chloride or metal ion contamination. 1100 aluminum has been found in both laboratory tests and in field experience to be an effective and economical substitute in this service. The aluminum alloy is corroded in the liquid phase at total acidities below 95 percent. 4.3.2

The specimens were suspended from glass trees in 500 cc Erlenmeyer flasks topped with ground glass stoppers. Where desired, provision was made for the introduction of special atmospheres into the flasks. Specimens were exposed to both liquid and vapor phases in the majority of the tests.

The commercially available 85-13.5-1.5 mixed acid was used in the preliminary tests. In the subsequent investigations, mixed acids were synthesized from C.P. 95.5 percent, sulfuric acid, distilled water and Baker & Adams technical grade anhydrous nitric acid. The small amount of water in the concentrated sulfuric acid was ignored in the calculations of total acidity. Chloride contamination was introduced as C.P. sodium chloride, and ferric and chromium ions as the C.P. nitrate salts.

The Erlenmeyer flasks were exposed in a shallow oil bath, controlled to 110 F ± 1 degree (43 C) by means of a thermoregulator, for periods varying from 24 to 300 hours. After exposure, the specimens were cleaned with soap, water and a soft brush, rinsed in water, dried in acetone, and reweighed. The corrosion rate in inches penetration per year (IPY) was calculated according to the formula:

$$\text{Pen. IPY} = \frac{526.8 \times \text{wt loss (gms)}}{\text{Density} \times \text{hrs exposure} \times \text{area (sq in)}}$$

Results

Initial tests on Type 347 were run in the liquid phase only. The results (Table 2) indicated that there was no appreciable liquid phase corrosion by the 85-13.5-1.5 mixed acid even when saturated with ferric or chromic ions or when contaminated by as much as 130 ppm of chloride ion. A time versus corrosion test gave a rate of .003 IPY at the end of 24 hours of exposure, diminishing to .0003 IPY after 300 hours of exposure.

Vapor-phase exposures in the commercial mixed acid showed high rates. A corrosion rate of 0.10 IPY was observed in the natural vapors, and when a slow stream of nitrogen or of dry air was charged to the flask. Wet air apparently increased the rate of attack (Table 3), but it is doubtful whether this is significant.

The attack of the vapor-phase specimen was characterized by condensation of the acid vapor on the surface of the coupons. As the condensate collected, drops fell from the specimens and encountered the liquid phase, the soluble salts being converted to the corresponding insoluble sulfate. The result was a deposition of sea-shell-like salts in the bottom of the flask. These conditions apparently duplicated those observed in the tank failure.

It was demonstrated in the laboratory tests that 1100 aluminum (formerly known as 2S aluminum) was not affected in either liquid- or vapor-phase exposure to the 85-13.5-1.5 mixed acid. All corrosion rates were less than .001 IPY, with no sign of pitting or irregular attack. A welded aluminum tank subsequently was installed, and has been used very successfully for several years with no corrosion difficulties except for occasional weld-leaks.

For purposes of general information, the investigation was extended to cover a variety of total acidities and sulfuric acid concentrations within the upper limits of the ICC regulations.

Table 4 illustrates the liquid phase corrosion of Type 347 under a variety of conditions. With the exception of the apparently anomalous results at 95 percent total acidity and 0 percent sulfuric, there is little corrosion below 100 percent total acidity. At 100 percent total acidity, the presence of sulfuric acid is apparently inhibitory. It will be observed that at 97 percent total acidity and 13.5 percent sulfuric (another commercially available mixture) even a sensitized Type 304 specimen is unattacked. This specimen had been heated at 1250 F for one hour to precipitate carbides at the grain boundaries and make it susceptible to intergranular corrosion.

In Table 5, the corresponding vapor-phase exposures are given. It will be observed that vapor-phase attack starts around 93-95 percent total acidity, and that the effect of the sulfuric acid is not well defined. A specimen of sensitized Type 304 in 83.5-13.5-3 mixed acid was very severely attacked and showed the granular appearance on the surface which is associated with intergranular attack. This is quite different from the smooth general vapor-phase corrosion of the annealed Type 347 specimen, and indicates that sensitization and "weld-decay" would be a factor to reckon with in vapor-phase exposure, although it would be of secondary importance.

Table 6 compares corrosion rates at 77 F (25 C) with those at 110 F (43 C) for vapor-phase corrosion of Type 347. There appears to be a marked diminution of corrosion in straight 100 percent nitric acid at the lower temperature. In other strengths and in mixed acid, the temperature seems to have little effect.

At 110 F (43 C) there is moderate to severe liquid-phase corrosion of 1100 aluminum below 95 percent total acidity (Table 7). At all strengths above 95 percent, the corrosion rate is low.

Table 8 shows that there are no significant vapor-phase effects on the aluminum alloy in any of the acid mixtures tested. It will be observed that for both liquid and vapor phase exposure, the 1100 aluminum is highly resistant above 95 percent total acidity. Data of the Manufacturing Chemists' Association, as reported by George Sands[3] illustrate essentially the same phenomena as have been reported above.

Discussion

The resistance of both the austenitic stainless steels and aluminum to attack by oxidizing acids is based upon the formation of a protective surface film. The maintenance of oxidizing conditions is essential for continued freedom from attack.

TABLE 1—Nominal Composition of Alloys Tested

	C		Cr	Ni	Fe	Others	
Type 347	.10 max.		17-20	8-12	Bal.	Cb 10 x C	
	Al	Fe+Si	Cu	Mn	Zn	Other, Each	Others, Total
1100 Aluminum	99.0	1.0 max.	.20 max.	.10 max.	.03 max.	.03 max.	.10 max.

TABLE 2—Corrosion of Type 347 in Liquid Phase of 85% Nitric—13.5% Sulfuric at 110 F After 300 Hour Exposure

Condition	Penetration in IPY
Blank	.000
Saturated with $Fe_2(SO_4)_3$*	.000
Saturated with $Cr_2(SO_4)_3$*	.000
Plus 130 ppm Cl⁻	.000

* Added as C.P. Nitrate Salts.

TABLE 3—Corrosion of Type 347 in Vapor Phase of 85 Percent Nitric—13.5 Percent Sulfuric at 110 F

Atmosphere	Penetration in IPY	Duration
Natural	.094	187 hours
Nitrogen	.100	48 hours
Air, dry	.105	48 hours
Air, 100% R.H.	.192	72 hours

TABLE 4—Corrosion[1] of Type 347 in Liquid Phase of Mixed Acids at 110 F After 168 Hour Exposure

	% TOTAL ACIDITY					
% Sulfuric	90%	93%	95%	97%	98.5%	100%
0	.003	.002	.027	.001	.....	.326
3	.001	.001	.001	.001	.....	.028
6	.001	.001	.001	.001	.....	.023
13.5	.....	.....	.....	.001	.001	.....
				.001*		

* Sensitized 304.
[1] Penetration is expressed in inches per year.

The exact degree of oxidizing capacity required of the liquor will be governed by the ease with which reduction of the protective film can be accomplished. Aluminum, which has only one valence state, apparently requires the oxidation capacity of the stronger nitric acid strengths for freedom from liquid-phase attack. On the other hand, the protective film is less easily reduced in vapor-phase exposures by the lower oxides of nithrogen.

According to Evans,[1] the cathodic reaction of austenitic stainless steels in nitric acid consists in the reduction of the acid. This may be expressed in stepwise fashion and from an ionic standpoint as shown in Equations 1, 2 and 3 below:

Cathodic reduction of nitric acid

$$NO_3^- + 2H^+ + e = NO_2 + H_2O \quad (1)$$

$$NO_2 + e = NO_2^- \quad (2)$$

$$NO_2^- + 2H^+ + e = NO + H_2O \quad (3)$$

Autocatalytic reaction

$$HNO_3 + HNO_2 = 2\,NO_2 + H_2O \quad (4)$$

Of these reactions, Equation 2 involves only two particles and is the most likely to proceed. The nitrous acid formed can generate more NO_2 in double the original quantity through reaction with excess nitric acid, as shown in Equation 4.

The concentration of both NO_2 and nitrous acid therefore will rise steadily until loss of nitrous acid by thermal decomposition or cathodic reduction to nitric oxide balances the increase. The attack therefore is autocatalytic and proceeds readily where nitrous acid can accumulate, as at crevices or in the vapor phase. Heterogeneity of the metal promotes this action by galvanic currents, as at the grain boundaries of sensitized stainless steel. Mixing or stirring tends to decelerate the action by diluting the nitrous acid formed. The presence of water appears to minimize the reaction, as might be expected from Equation 1. Addition of urea, which reacts with HNO_2, effectively retards the reaction. The presence of sulfuric acid should increase the phenomenon by lowering the activity of any water present. That it does not appear to do so may be a result of the enhancing of the existing surface films with supplementary sulfate films. The data on the effect of sulfuric acid are, the author feels, inconclusive. A positive effect on this vapor-phase attack possibly due to hydrolytic tendencies of nitrosyl-sulfuric acid has been reported.[4]

The Subcommittee on Mixed Acids for the Manufacturing Chemists Association carried out field exposure tests which indicated that sulfuric acid influenced the corrosion rate in the vapor phase of stainless steel drums. Mixed acid, containing 85 percent nitric and 14 percent sulfuric, was stored in Type 347 drums under atmospheric conditions at the Hercules Powder Company plant in Parlin, N. J. The vapor phase was corroded deeply, whereas the liquid phase showed no evidence of corrosion. The vapor phase attack in this instance was many times greater than normally would be obtained in the storage of 85 to 99 percent nitric acid.

One of the problems raised by the facts reported herein is the question of why shipping containers for nitric and mixed acids do not have a shorter life than they do. The rates found in the laboratory are excessive, but Type 347 stainless steel is used successfully in the shipment of up to 102 percent nitric acid. The answer probably lies in the washing action of the liquor in a well-filled container. The stirring and mixing which results from any movement of the container would tend to dilute the nitrous acid formed and slow down its interaction with the nitric. Under quiescent conditions or in a storage tank, this washing action is not encountered. Therefore severe vapor phase attack may be encountered even though the acid might be successfully shipped in a container of similar material.

In the failure of the Type 347-clad tank which precipitated this investigation, the acid level rose and fell slowly. The tank would be filled from a tank-car shipment of mixed acid, and then the liquid level would fall slowly as acid was used. For this reason, severe *vapor-phase* corrosion was encountered over nearly all the internal surface of the tank, with the exception of the very bottom.

At the present time, the aluminum storage tank

TABLE 5—Corrosion[1] of Type 347 in Vapor Phase of Mixed Acids at 110 F After 168 Hour Exposure

	% TOTAL ACIDITY					
% Sulfuric	90%	93%	95%	97%	98.5%	100%
0	.001	.012	.020	.073	.....	.155
3	.002	.036	.043	.045	.....	.141
6	.001	.003	.061	.126	.....	.107
13.5	.....	.....	.....	.062 .331*	.105	.....

* Sensitized 304.
[1] Penetration is expressed in inches per year.

TABLE 6—Comparative Corrosion of Type 347 in the Vapor Phase of Mixed Acids at 77 and 110 F After 168 Hour Exposure

	77 F			110 F		
	% Total Acidity			% Total Acidity		
% Sulfuric	90	95	100%	90	95	100%
0	.000	.003	.044	.003	.027	.326
3	.000	.001	.020	.001	.001	.028
6	.000	.002	.020	.001	.001	.023

TABLE 7—Liquid Phase Corrosion[1] of 1100 Aluminum in Mixed Acids at 110 F After 168 Hour Exposure

	% TOTAL ACIDITY					
% Sulfuric	90%	93%	95%	97%	98.5%	100%
0	.092	.032	.002	.000	.....	.002
3	.015	.018	.003	.002	.....	.001
6	.057	.015	.007	.002	.....	.000
13.5	.....	.....	.....	.004	.001	.....

[1] Penetration rate is expressed in inches per year.

TABLE 8—Vapor Phase Corrosion of 1100 Aluminum in Mixed Acids at 110 F After 168 Hour Exposure

	% TOTAL ACIDITY					
% Sulfuric	90%	93%	95%	97%	98.5%	100%
0	.008	.006	.004	.002	.....	.002
3	.008	.006	.003	.002	.....	.002
6	.008	.004	.004	.003	.....	.001
13.5	.....	.....	.....	.002	.001	.....

has successfully handled two commercially available mixed acids, 85 nitric-13.5 sulfuric-1.4 water and 13.5 percent sulfuric-83.5 percent nitric-3 percent water, for four years.

Conclusions

The following conclusions may be drawn from the data presented:

1. Failure of a Type 347 stainless steel-clad tank was caused by vapor-phase corrosion by the fumes of a mixed acid of the composition 85 percent nitric-13.5 percent sulfuric-1.5 percent water.
2. Replacement with a tank fabricated from 1100 aluminum is an effective and economical solution.
3. The resistance of the austenitic stainless steel storing straight or mixed nitric acid is suspect at concentrations in excess of 95 percent total acidity, inasmuch as it may become subject to severe vapor-phase attack under quiescent conditions.
4. The vapor-phase corrosion of stainless steel may not be encountered in shipping containers because of the stirring and mixing of the solution during transportation or other movement.
5. At total acidities higher than 95 percent, 1100 aluminum appears to be unaffected in either liquid or vapor-phase exposures.

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Any discussions of this article not published above will appear in the June, 1957 issue.

A High Potential Magnesium Anode*

By P. F. GEORGE, J. J. NEWPORT and J. L. NICHOLS

Abstract

Extensive research work on magnesium alloy anodes has produced a new high potential material which will deliver from 20-30 percent more current to a polarized cathode than the conventional alloy anodes presently employed. Data obtained from these tests further indicate that this new anode exhibits marginally less current efficiency in normal soils when compared with Grade A Mg-6 percent Al, 3 percent Zn alloy, whereas, in saline environments the ampere-hour recovery from this high potential anode is equal to or greater than that obtained from Grade A magnesium alloy. Polarization characteristics and corrosion patterns observed with the new anode are comparable to those seen on the conventional Mg-6 percent Al, 3 percent Zn alloy.

A comparison of microstructures from commercial magnesium and the new alloy offers a possible mechanism explaining the superiority of this new material as a sacrificial anode. This is based on the coating of impurity particles with manganese rendering them less harmful as contaminants.

Field data presented by cooperating companies verify the claimed current output advantage of the new high potential anode when measured against a polarized cathode, and demonstrate the dependence of the incremental advantage on the cathode-to-soil solution potential. The economics of cathodic protection using galvanic anodes favor the use of the high-potential anode in almost all applications. **5.2.2**

Introduction

THE CONSTANTLY increasing use of cathodic protection for corrosion mitigation on various domestic and industrial structures and equipment has aroused widespread interest in new developments and applications of galvanic anodes. Considerable effort has been made to improve the important properties of these anodes through considerations of metal purity,[1] alloying agents[1,2] and anode backfill material.[3] Primary emphasis in these studies has been placed on improvement of current efficiency, polarization characteristics, and distribution of corrosion attack at the anodes. The anode solution potential is also significantly important, because it is the algebraic difference between the cathode and anode half cell potentials which determines the net driving potential; hence, assuming no change in cathode potential or circuit resistance it can be seen that any increase in anode potential may be translated into increased anode current output.

The extra driving force afforded by a high potential anode is especially desirable in high resistivity soils and where the cathode structure is relatively inaccessible. Furthermore, in normal soils an anode with increased potential would bring about a decrease in installation costs since fewer anodes would be required to satisfy the current requirements of a particular structure.

For these reasons considerable effort has been advanced in the last several years toward the development of a sacrificial anode having a relatively high solution potential. For years it had been known that commercially pure magnesium possessed a high solution potential; however, the current efficiency of this material was not dependable. Finally, a new low-alloy composition containing manganese was developed. This new high potential anode alloy is sold under the trademark of Galvomag.[(1)]

Properties of Galvomag

In selecting and comparing metals to be used as sacrificial anodes, the properties mentioned previously become the primary considerations; however, on occasion a compromise may be favored because of an outstanding need for one particular property. In general, the best anode will be obtained where the optimum is met with each of the following properties:

1. *Potential*

The solution potential of the anode material with respect to the structure metal to be protected must be sufficiently more anodic to properly polarize the local cathodes of the latter metal. Additional voltage offers the advantage of greater throwing power which may be interpreted as a reduction in the number of anodes required and a corresponding reduction in installation costs, or as additional protection on a structure which may be relatively inaccessible to normal current flows. Laboratory and field data have shown that this material has an inherent potential of approximately 180 millivolts greater than the Grade A Mg-6 percent Al, 3 percent Zn (H1) alloy. This potential advantage is necessarily an average since this figure is dependent on a large number of variables whose standard deviations are relatively large. Impurity content, distribution of impurities, crystal orientation, anode environment, instrumentation and measuring technique are only some of the factors which influence the observed values of anode solution potentials. Hence, measured potentials of the Galvomag anode will show some variance, similar to that observed with other galvanic anode materials. Generally, the measured advantage will fall between the limits of 140 to 220 millivolts. Assuming a constant circuit resistance, the increased solution potential of the new anode may be expected to contribute 20-30 percent more current than would be obtained from an H1 alloy anode when the cathode is polarized to a protective potential (assume —0.85 volt: reference: Cu-$CuSO_4$).

* Submitted for publication September 29, 1955. A paper presented at a meeting of the South Central Region, National Association of Corrosion Engineers, Houston, Texas, October 18-21, 1955.

(1) Trademark of The Dow Chemical Company, Midland, Michigan. Patent applied for.

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Another method of obtaining greater current flow is found in the reduction of the anode-to-cathode circuit resistance. Because the circuit resistance is an inverse function of the cross sectional area of the current path, the current output of a given material is also dependent to a considerable extent on the length of the anode. Hence, it is possible to obtain even more current for a particular application by increasing the anode length. This new anode has been extruded into long lengths for those applications where current starvation at the cathode is a problem. These are available in 1½-inch and 2-inch diameter rods extruded over an iron core and cut into 10 foot lengths. Laboratory data on this extruded material have shown current efficiencies as good or better than the cast metal at the same current densities.

2. Current Efficiency

The theoretical electrochemical equivalent of magnesium is approximately 1000 ampere hours per pound. However, because of side reactions, the theoretical current yields are seldom realized in practice, and therefore, the need exists for determining

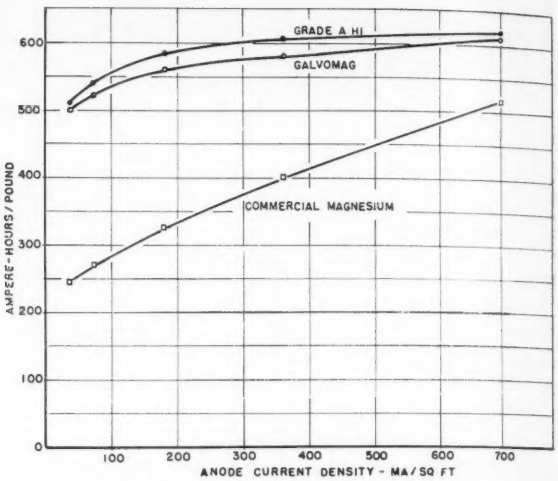

Figure 1—Current efficiency versus anode current density. Tests were run on three types of magnesium anodes in saturated $CaSO_4$.

current efficiency and how it is affected by various operational and environmental factors. The importance of anode efficiency, in most cases, cannot be overemphasized because this figure is a measure of electrical power, and dollars saved, to the purchaser. In general, the maximum current efficiency is sought, consistent with the retention of other desirable anode properties.

Figure 1 is a plot of current efficiency versus anode current desity for: (1) Mg-6 percent Al, 3 percent Zn alloy, (2) Commercial "cell" magnesium, and (3) Galvomag, based on laboratory tests in a saturated $CaSO_4$-saturated $Mg(OH)_2$ electrolyte. Galvomag shows efficiencies which are slightly less than those seen with Grade A Hl alloy. However, in most soil applications the anodes tend to operate in the lower current density range where the efficiency superiority of Hl alloy either disappears or is reduced to a marginal difference. Figure 1 further shows the large advantage of these two anode materials over cell magnesium. The latter material had been used as a galvanic anode several years previous but because of the observed undependability efficiency-wise, the economics favored abandonment of this material as a sacrificial anode.

The curves shown in Figure 1 were obtained using standard laboratory testing techniques which have been described in a previous publication.[2] It may be noted that the increase in efficiency with increasing current density roughly parallels the Hl alloy curve.

Figure 2 shows current efficiency data for the new anode as a function of sodium chloride additions to a saturated $CaSO_4$-saturated $Mg(OH)_2$ electrolyte at a current density of 72 ma/sq ft. Previous experience has shown that the efficiency of Hl alloy at this current density has been lowered somewhat by increasing NaCl concentrations. From this curve it may be predicted that this anode would gradually assume the advantage over Hl alloy in high salt soils, as the NaCl content is increased.

3. Polarization Characteristics

In view of the fact that the increased solution

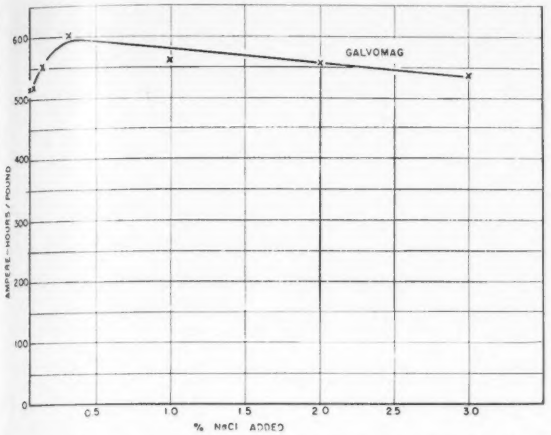

Figure 2—Effect on anode efficiency of Galvomag from adding NaCl to saturated $CaSO_4$ electrolyte. Anode current density is 72 ma/sq ft.

potential of the new anode is its outstanding attribute, the retention of this high value as affected by time, environment and anode current density is of major concern. In general, a desirable anode material exhibits a minimum of polarization with respect to: (1) Long time exposures, (2) A wide range of current densities, and (3) A maximum number of different environments. Galvomag has shown polarization characteristics which are similar to Hl alloy in all of the tests run to date. Field data have exhibited no reductions in potentials and current flow except those which may be attributed to seasonal changes. These results have been obtained from both bare and backfilled anodes buried in soils with resistivities from 100 to 15,000 ohm-cm. Measured potentials in standard laboratory tests have shown comparable results in saturated $CaSO_4$ and 3 percent NaCl solutions over a range of anode current densities.

4. Corrosion Pattern

Because of the fact that the current efficiency of any anode depends to some extent on the uniformity of corrosion attack, it is important that particular attention be given the corrosion pattern. It is quite possible that the segregation losses from an anode exhibiting a poor corrosion pattern may more than counteract any efficiency gain obtained from metal composition. Galvomag has a pattern of corrosion attack different in appearance from that exhibited by Hl alloy, although the uniformity of consumption of the two anodes is similar. The new anode may exhibit a bright appearance whereas the Hl is mottled gray.

Composition and Microstructure

Magnesium alloys previously used as commercial galvanic anodes gave low current efficiencies except when the iron content was kept at very low levels. In the new anode higher iron contents can be tolerated without a detrimental effect on current efficiency. The reasons for this, though not fully understood, are thought to lie in the metallurgical state of the alloy, particularly in the distribution of iron between the magnesium-rich and manganese-rich phases present in the alloy.

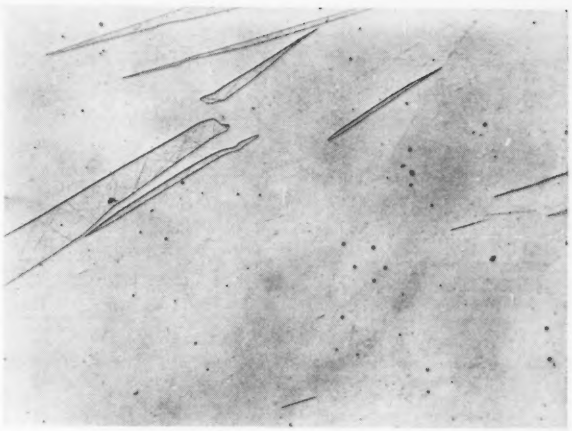

Figure 3—Photomicrograph of commercially-pure magnesium showing a few scattered manganese particles and mechanical polishing twins. Five percent Nital etch; 83X.

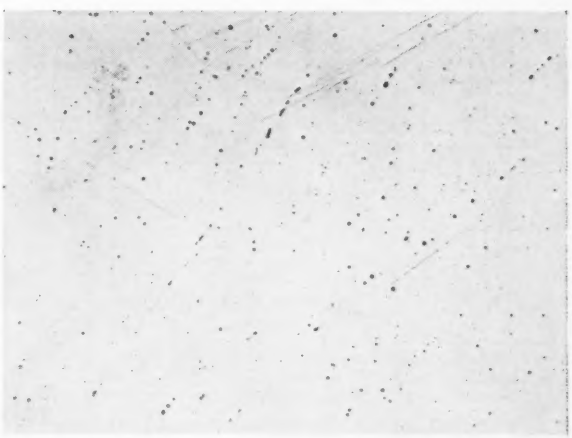

Figure 4—Photomicrograph of Galvomag showing an abundance of manganese precipitation. Several mechanical polishing twins are also evident. Five percent Nital etch; 83X.

In pure magnesium, iron, at levels in excess of its solid solubility, is invariably detrimental to efficency. The magnitude of the effect at any given level depends upon the degree of dispersion of the iron particles. The introduction of a second component of suitable properties, in this case manganese, offers a means of combatting the adverse effect of iron without actually removing it. Manganese is indicated because:

(1) It is feebly cathodic to magnesium, much less so than iron.
(2) It has limited solubility in magnesium, giving an alloy rich in second phase manganese at relatively low manganese levels.
(3) Iron is more soluble in manganese than in magnesium.

The above properties enable manganese to combat the effects of iron by any one or a combination of the following mechanisms:

(1) Precipitation on and envelopment of in-

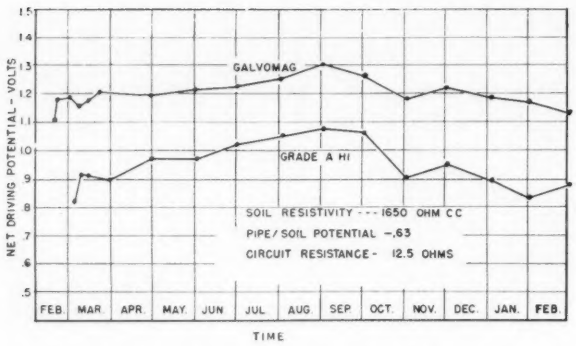
NET DRIVING POTENTIAL - VOLTS
GALVOMAG
GRADE A HI
SOIL RESISTIVITY --- 1650 OHM CC
PIPE/SOIL POTENTIAL -.63
CIRCUIT RESISTANCE - 12.5 OHMS
FEB. MAR. APR. MAY. JUN JUL AUG SEP. OCT. NOV. DEC. JAN. FEB.
TIME

Figure 5—Comparison of net driving potential of 17-pound Galvomag and Grade A H1 anodes in the field.

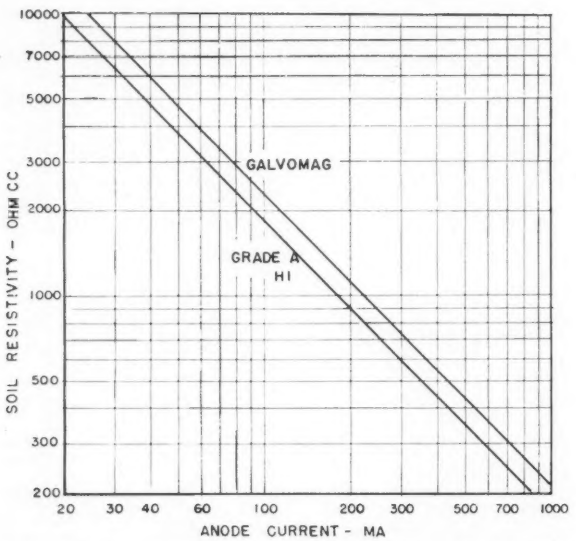

Figure 6—Current expected from 17-pound Galvomag and Grade A H1 anodes in various soils. Anodes are 10 feet from 8-inch bare pipe line with pipe-to-soil potential of —0.85 volt.

soluble iron particles by manganese during the freezing and cooling process (casting). This effectively eliminates local galvanic cells by coating the strongly cathodic iron with feebly cathodic manganese.

(2) Extraction of iron from the magnesium-rich phase by solution in the second phase manganese. The greater solubility of iron in manganese argues for preferential dissolution of iron in the manganese-rich phase with an attendant reduction in its capacity for corrosion damage. Experimental evidence shows that iron in solid solution has little or no adverse effect.

(3) Precipitation and removal of iron by gravitational settling along the lines indicated by (1) above. Manganese has been used extensively to remove iron from the Mg-Al and Mg-Al-Zn alloys by settling but, in the case of Galvomag,

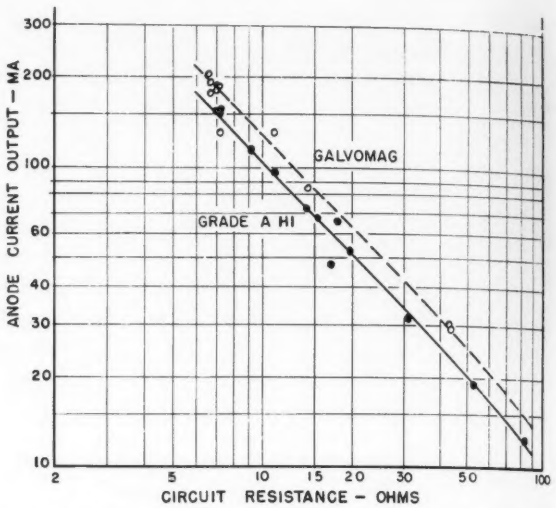

Figure 7—Current output versus total circuit resistance comparison of Galvomag and Grade A H1 anodes. These 17-pound backfilled anodes were in 1500 to 15,000 ohm soils.

settling is not attempted and any reduction in iron level is inadevertent.

Metallographic and electron diffraction studies show the new anode material to be much richer in second phase manganese than cell magnesium as indicated by the microstructures shown in Figures 3 and 4 but neither method has conclusively shown which of the above mechanisms contributes most of the beneficiation. Light microscope studies at high magnifications strongly indicate that mechanism (1) is operative but the mechanisms postulated under (2) is simply informed speculation.

Figure 3 shows the structure of "cell" magnesium, exhibiting a few scattered manganese particles, with the majority of the detrimental impurities remaining unresolved at this magnification. In sharp contrast, Figure 4 shows an abundance of manganese rejected from solution and is typical of a high-efficiency Galvomag. The lenticular markings in both figures are twins which are prevalent in relatively pure magnesium microstructures. Previous observations at very high magnification on manganese-containing magnesium have shown an apparent manganese coating on the ferriferous particles giving a fish-eye appearance.

While the major difference between cell magnesium and the new anode appears to involve only manganese content, experience has shown that certain common impurities in cell magnesium seriously interfere with upgrading by manganese and must be controlled to get acceptable anode properties. It has also been found that the anode properties of this high potential anode are heavily dependent on the thermal history of the cast alloy in that too prolonged an exposure in certain temperature ranges will markedly and adversely affect its properties. This requires that careful attention be paid to casting practice.

Field Data

The outstanding advantage of the new anode

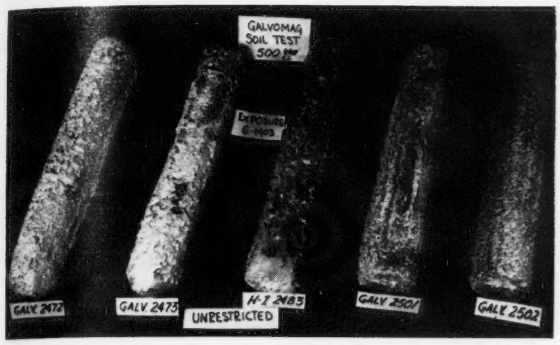

Figure 8—Corrosion pattern comparison of Galvomag and Grade A H1 alloy field test specimens. Anodes were removed from 500 ohm-cm soil after six months exposure.

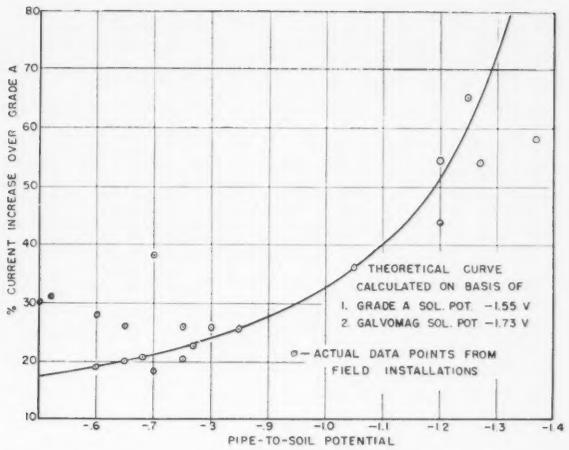
% CURRENT INCREASE OVER GRADE A
PIPE-TO-SOIL POTENTIAL
THEORETICAL CURVE CALCULATED ON BASIS OF
1. GRADE A SOL. POT. −1.55 V
2. GALVOMAG SOL. POT −1.73 V
ACTUAL DATA POINTS FROM FIELD INSTALLATIONS

Figure 9—Effect of pipe-to-soil solution potential on percent current increase of Galvomag over Grade A H1.

material is its high current output. This is best demonstrated by a typical set of data shown in the curves of Figure 5. These data were obtained by installing 17-pound anodes of high purity H1 alloy and Galvomag on an eight-inch, bare underground pipe line having an average pipe-to-soil potential during the test of —0.63 volt (reference: Cu-$CuSO_4$ electrode). Measurements were made of the total circuit resistance using a megger-type instrument, and of the current flow by measuring the voltage drop across a calibrated 0.1 ohm shunt. The net driving potential was then calculated by Ohm's Law from the current flow and total circuit resistance and plotted versus time in Figure 5. By this method the two anode materials can be compared directly, even though the soil resistivity changes somewhat between the test locations. Many such field tests were made in various soils from 100 to 15,000 ohm-cm resistivity and, in every case, the data substantiated the laboratory results and showed Galvomag to have 20-30 percent more driving voltage.

From the data shown in Figure 6 it is possible to predict the amount of current that the new high potential alloy will produce in comparison with high purity H1 alloy in various soils at one level of pipe potential.

Figure 7 shows the results of the field test measurements obtained in the same manner as described for Figure 5; it compares the current output of Galvomag and high purity 6 percent Al, 3 percent Zn alloy as a function of total circuit resistance. The pipe line which served as a cathode for these installations was underprotected purposely (—0.63 volt with reference to a Cu-$CuSO_4$ electrode) in order to determine maximum current flows from these experimental anodes. These anodes represent material which has been in the field from one to two years. These Galvomag installations have consistently produced 20 to 30 percent more current than have the Grade A magnesium alloy anodes installed under comparable conditions.

Current efficiency measurements on 17D backfilled Galvomag anodes removed from the field have further substantiated laboratory tests. Thirty-one anodes removed from high salt soils (100-300 ohm-cm) have averaged 470 ampere-hours/pound after six months exposure at current densities of 30-180 milliamperes per square foot. This compares very favorably with an average of 472 ampere-hours/pound for the four H1 control anodes submitted to identical exposures.

Measurements from eight high potential anodes removed from low salt soils (500-1200 ohm-cms) after six months gave an average current efficiency of 467 ampere-hours/pound at similar current densities.

Four high potential anodes were removed from field tests in 1500-15,000 ohm-cm soil. These anodes operated at a current density of 30-80 milliamperes per square foot and showed a yield of 480 ampere-

TABLE 1—Supplementary Field Data Showing Comparison of Galvomag and HI Alloy 17-Pound Anodes

Company	P/S Potential (Cu-$CuSO_4$)	Soil Resist. (ohm-cm)	Percent Current Increase	Remarks
A	—0.60 —0.50 —1.27 —1.25	4500 3300 1915 2572	28 30 54 65	4 months on test 4 months on test 1½ months on test 1½ months on test
B	—0.70	10,000	88	Low H1 Alloy
C	—0.75	2500–3000	20.5	7 months on test
D	—0.68	High	20.5	3 months on test
E	—0.67 (H1) —0.85 (GM)	1000 to 15000	15*	3 months on test
F	—1.38 —0.77	4000 to 12000 4000 to 12000	58 22.5	3 months on test 2 months on test
G	....	14000 to 33000 7680	63 9	2 months on test 2 months on test
H	—0.70 —0.80 —0.60 —0.65	13000 4800 8600 9200	38 26 19 20	10 days on test 10 days on test 10 days on test 10 days on test
I	—0.70	3000 to 8000	18.5	6 months on test
J	—0.65	1000 to 15000	26	10 months on test
K	—1.29 —1.41	....	133 346	{Low H1 Alloy {3 months on test
L	—1.20	2000 to 6000	43.6	.....
M	—1.05	....	36	2 months on test
N	—0.53	20,000	58	.....
O	—0.85	....	25.6	2 months on test
P	—0.52 —1.20	300 to 700 14000	31 54.5	....

* With same P/S for H1 and GM the percent current increase would be 34 percent (for —0.67 volt) and 41 percent (for —0.85 volt).

hours/pound with a very small amount of scatter. Two conventional alloy control anodes averaged 475 ampere-hours/pound under similar conditions.

In the foregoing tests, both the Mg-6 percent Al, 3 percent Zn alloy and the new anode exhibited current efficiencies 20-50 ampere-hours/pound under that predicted by laboratory tests. Past experience, however, has shown that on longer exposures these values would be expected to approach the laboratory averages. This may be attributed to minor skin effects in the form of segregation and surface contamination.

The corrosion pattern of the anodes removed from the field test installations is similar to the characteristic attack on Grade A Hl alloy. The consumption is smooth and uniform at the higher current densities, and deteriorates to a shallow pitting type of attack at the very low densities. Figure 8 is a photograph of four Galvomag anodes with a Grade A Hl control which were a part of the field testing program, and shows the corrosion pattern on the two anode materials.

Other Field Tests

In order to supplement the tests run by this laboratory, many companies volunteered to assist in the field testing program for the new anode. These companies have cooperated completely, to the extent of obtaining operating data on the high potential anode and its behavior compared to the 6 percent Al, 3 percent Zn alloy, each company recording measurements taken from four to six high potential anodes. These data were compiled in this laboratory and are presented in Table 1. This tabular data presents the percent current increase over Grade A of Hl alloy observed by each cooperating company, along with the soil resistivities and cathode-to-soil potentials of the protected structures. The results shown in Table 1 vary in exposure duration from 10 days to 7 months.

The operating data presented in Table 1 are more easily interpreted when plotted graphically as in Figure 9. There, the percent current increase of the new anode over Grade A Hl alloy is plotted as a function of the pipe-to-soil potential. The solid curve in Figure 9 is a theoretical curve based on Ohm's Law utilizing the following assumptions: (1) Grade A Hl solution potential at —1.55 volts (reference Cu-$CuSO_4$ electrode) (2) Galvomag solution potential at —1.73 volts (reference Cu-$CuSO_4$ electrode) and (3) A constant circuit resistance for purposes of comparison.

It can be seen that the percent current increase of the new anode over Hl alloy necessarily approaches infinity as the difference between the solution potential of Grade A Hl alloy and the pipe-to-soil potential approaches zero. The data points presented in this graph represent the field data obtained from the various companies participating in the field testing program. The coincidence of these field data points with the theoretical curve is remarkable when the variety of installations and types of instrumentation are considered. Those points which exhibit the largest amount of scatter, fall on the high side of the curve which suggests that the assumption of 180 millivolts advantage of Galvomag is on the conservative side.

Further reference to Figure 9 indicates that the published advantage of 20-30 percent more current from the high potential anode necessarily depends on the pipe-to-soil potential and hence, is based on a polarized cathode, (i.e., a solution potential of —.80 to —.85 volts when measured with a Cu-$CuSO_4$ half-cell.) If the cathode potential is very low (e.g., —0.50 volt) then only 15 to 20 percent more current may be expected. However, in the region where the extra driving force is needed, the high potential anode will produce the additional 20-30 percent increased driving force as claimed.

An excellent example of the dependence of the 20-30 percent current increase on the pipe-to-soil potential may be seen in Table 1. Company E reported observing only a 15 percent current increase for the new anode over the conventional anode. Closer inspection showed the pipe-to-soil solution potential for the installations to be —0.85 volt compared to —0.67 volt for the Hl anodes. Thus, when the current advantage was calculated on a basis of the same pipe-to-soil potential for both anodes, the expected superiority of Galvomag was observed, giving current differentials of 34 and 41 percent for pipe-to-soil potentials of —0.67 volt and —0.85 volt respectively. This has been observed in other tests where the pipe adjacent to the high potential anode installation has been polarized to a more negative value because of the higher current flows.

It is obvious here that where the cathode is polarized to a high negative value, an apparent current wastage is experienced in many applications. This serves, however, as a sound basis for making fewer anode installations where this particular problem is met, since the increased current output and throwing power of the new anode will compensate for a 25 percent reduction under the number of Grade A Hl alloy anodes which would be needed. At the same time, the inherent potential of this anode provides the additional throwing power needed for the protection of structures in high resistivity soils. Hence, the economics of the protection of underground structures using galvanic anodes favors the use of Galvomag in almost every instance.

Summary

Laboratory and field tests during the past several years have shown that Galvomag will deliver from 20-30 percent more current to a polarized cathode than the conventional alloy anodes presently employed. Data obtained from these tests further indicate that this anode exhibits marginally less current efficiency in normal soils when compared with Grade A Mg-6 percent Al, 3 percent Zn alloy, whereas, in saline environments the ampere-hour recovery from Galvomag is equal to or greater than that obtained from Grade A magnesium alloy. Polarization characteristics and corrosion patterns observed with the high-potential anode are comparable to those seen on the conventional Mg-6 percent Al, 3 percent Zn alloy.

A comparison of commercial magnesium and Galvomag microstructures offers a possible mechanism

explaining the superiority of this new material as a sacrificial anode. This is based on the coating of impurity particles with manganese rendering them less harmful as contaminants.

Field data presented by cooperating companies verify the claimed current output advantage of Galvomag when measured against a polarized cathode, and demonstrate the dependence of the incremental advantage on the cathode-to-soil solution potential. The economics of cathodic protection using galvanic anodes favor the use of the high-potential anode in almost all applications.

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Any discussions of this article not published above will appear in the June, 1957 issue.

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A Technical Note

A Case History of Stress Corrosion Cracking Of Austenitic Stainless Steel*

By I. D. G. BERWICK*

Abstract

The stress corrosion cracking and pitting of stainless steel strainer plates used in pulp mill digesters is discussed. Consideration is given to the part played by internal and external stresses in bringing about plate failure; the corrosive nature of the environment is also considered. A stress-relieving treatment designed to alleviate cracking is described. It was found that a molybdenum-bearing stainless steel heat-treated at 1550-1600 F for 30 minutes followed by air or furnace cooling, showed no tendency to stress corrosion even in severely corrosive media. With face plates made from Type 317 alloy, stress corrosion was eliminated and pitting corrosion greatly reduced. 3.5.8

Introduction

RECENTLY AN INTERESTING case of stress corrosion cracking was encountered in stainless steel strainer plates used in pulp mill digesters. The strainer plates were installed on the inner circumference of the digesters so as to form an annular ring through which the cooking liquor was withdrawn. A circulating pump returned the liquor to the digester at a remote point so as to distribute heat uniformly through the digester. The plates prevented wood chips from circulating with the liquor.

Calcium-based sulfite liquor containing 1.1 percent combined sulfur dioxide and 7.5 percent total sulfur dioxide, together with wood resins and traces of chlorides, was circulated at a temperature of approximately 144 C. The pH of the liquor varied somewhat during the cook but averaged 3.0.

In the complete ring there were 43 separate plates, each consisting of a cast frame made of Type 317 stainless steel and a Type 316 facing plate tack-welded to the frame. The facing plate was bent along two lines so as to give it a U-shaped section and was perforated with a large number of drainage holes.

After service periods as short as six weeks the plates pitted and became coated with a very adherent calcium sulfate-wood resin scale. In addition, the face plates suffered severe bursting failure at the bends, the metal appearing to have lost all strength at the points of failure. No signs of corrosion or fracturing were noted on the frames, however. Attempts were made to repair the pits and fractures by patch welding, but this measure resulted only in further failures in even shorter service periods.

Investigation

Samples of the failed plates were descaled by soaking in "Sequestrene" (disodium-ethylene-diamine-tetra-acetate) and by wire brushing. The appearance of one of the descaled samples is shown in Figure 1. After scale removal a number of cracks were observed in the plates, extending from one drainage hole to an adjacent hole. Micrographic examination of the plates showed that the stainless steel was severely fractured with branching transgranular cracks running in all directions. The most severely cracked metal was located close to the holes and it also was noted that the austenite grains close to these holes showed signs of considerable internal stresses, many of them being striated with strain markings along internal slip planes. Figures 2 and 3 indicate the extent of the cracking.

Cause of Failure

Although stress-corrosion cracking of stainless steel components is comparatively rare, austenitic stainless steels are susceptible to this type of failure in certain environments. The path of failure is almost always transgranular, although there have been isolated cases of intergranular failure. According to Scheil[1] "when transgranular cracks are identified in the failure of stainless steel alloys in service this is

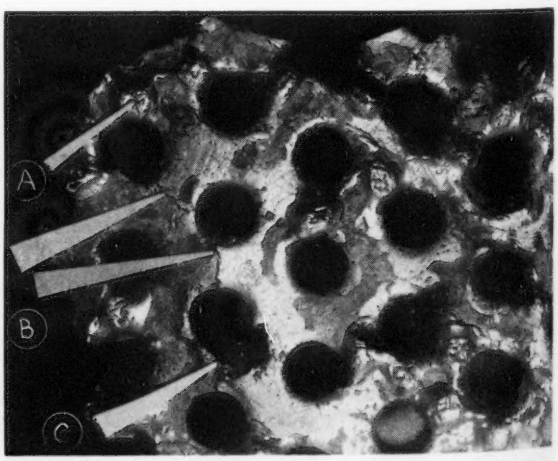

Figure 1—Appearance of strainer plate after descaling. Code is as follows: A, weld bead; B, cracks; C, corrosion pit. Plate is slightly larger than actual size.

★ Submitted for publication July 11, 1956.

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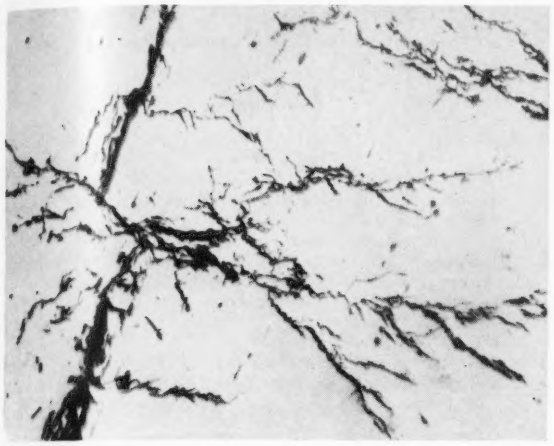

Figure 2—Unetched micro-section of plate showing large number of branched cracks. 81X.

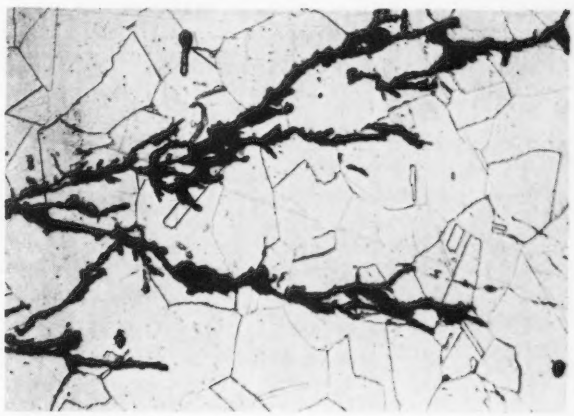

Figure 3—Etched micro-section of plate showing equiaxed austenite grains and transgranular cracking. Electrolytic oxalic acid etch. 152X.

a definite sign of stress corrosion." Other investigators have observed that stress-corrosion cracks have a very typical branched formation[2,3,4] which closely corresponds to the cracking observed in the strainer plates. It appeared therefore, that the bursting failure and loss of strength of the strainer plates was due primarily to stress corrosion of the stainless steel, and consideration was given to the methods of plate fabrication and the operating conditions in the digester.

There is no doubt that the cooking liquor provided an environment conducive to stress corrosion. In acidic solutions small amounts of chlorides can produce stress corrosion of stainless steels[1,2,4,5] and solutions containing hydrogen sulfide and other sulfur-containing substances also are dangerous,[6] particularly when associated with reducing conditions.[7]

The stresses required to produce stress-corrosion cracking may be extremely low.[1] Cold working, quenching, grinding, welding, or restrained thermal expansion can all introduce internal stresses far in excess of the value required to render stainless steel susceptible to stress corrosion cracking.

The face plates had been fabricated by drilling and bending and stress relieving at 2000 degrees F followed by a water quench. Thus, although the machining and bending stresses were relieved by the heat soaking, other undesirable stresses were introduced by the water quench. In addition, further stress was introduced by the cold straightening which was found to be necessary in order to remove the distortion caused by the heat treatment, and also during stitch-welding of the face plates to the frame. Patch-welding the pits after a period of service undoubtedly introduced further stresses.

Besides these internal stresses there is the possibility that external stresses also contributed to the failure. These are likely to have arisen from flexing of the plate during operation or during blow-down, or from scale build-up on the frame forcing the face plate towards the center of the digester.

The presence of slip lines in some of the austenite grains is a strong indication that undesirably high stresses were, in fact, present in the plates.

In view of these considerations, it was concluded that the mode of failure was stress corrosion, both the requisites for this type of failure, a corrosive medium and appreciable stress, being present in the system.

The mechanism of the pitting corrosion appears to be complex. However, the tendency of solutions containing chlorides to pit stainless steels is well known and the action of the small amount of chlorides present undoubtedly would be accelerated by the operating temperature and pH. In addition, it is known that sulfurous gases corrode some stainless steels, apparently by destroying the protective oxide film on the surface.[8] There is also the possibility that partial shielding of the surface by scale deposits formed oxygen-concentration corrosion cells.

It seemed probable that the pits, although not directly connected with the stress corrosion cracking, could nevertheless act as stress raisers from which the cracks could propagate readily.

Remedial Measures

The principal method of preventing stress corrosion is to carry out some stress-relieving treatment in order to remove or reduce residual internal stresses, and to design the component so as to avoid unduly high external stresses. Inasmuch as the benefits of stress relief are lost if the article is subsequently cold-worked or subjected to thermal stresses, it was recommended that the strainer plates be punched, bent and tack-welded to the frames, and that the completed units be heat-treated. Scheil[1] found that a molybdenum-bearing stainless steel heat-treated at 1550-1600 degrees F for 30 minutes followed by air or furnace cooling, showed no tendency to stress corrosion even in severely corrosive media.

Because intergranular chromium carbide precipitation occurs in the temperature range 900-1560 F some degree of sensitization is to be expected during

the heat treatment. In order to avoid this problem it was recommended that a low-carbon alloy be used.

In order to minimize the pitting attack it was recommended that a Type 317 alloy be used for making the face plates. This alloy, with a higher molybdenum content than Type 316, withstands the cooking liquor very well, judging by the Type 317 frames, which remained in excellent condition.

These proposals were adopted by the pulp mill, with the exception that the Type 317 plates were tack welded to the frames in three separate sections, thereby eliminating the bending operation. Since that time there has been no stress corrosion cracking of the strainer plates, all the plates being in good condition after almost a year of operation, apart from slight vertical distortion due to service conditions. The pitting corrosion also has ceased to be a serious problem.

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Any discussions of this article not published above will appear in the June, 1957 issue.

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Role of Minor Elements In the Oxidation of Metals*

By EARL A. GULBRANSEN

Introduction

IT HAS BEEN known for some time that impurities have a major effect on the oxidation of metals. In fact, it is an interesting philosophical question as to what extent reactions actually would occur on a pure metal free from inclusions, defects, dislocations, etc. In a recent paper, Gulbransen and McMillan[1] have considered the role of minor amounts of certain elements on the oxidation of nickel-chromium alloys. As a result of that work, studies were initiated to further the understanding of the role of impurities and minor elements in oxidation. In the present paper, the term impurity will be used in a broad sense; namely, the presence of foreign atoms in the metal, either in solid solution or as a precipitated phase. Thus, foreign atoms present to several weight percent will be considered as impurities.

The first objective is to classify the various impurity effects. This may be done by considering the effect of impurities on the physical and chemical structure of the oxide, oxide-metal interface and metal. Figure 1 shows a schematic summary of the various effects. Each of these will be discussed in turn and where experimental evidence is available, this will be used to illustrate the nature of the effect.

Discussion and Experimental Results

Formation of New Oxide of Impurity Atoms in Outer Layer

Several conditions must be met if the impurity atom is to form its own oxide in the outer layer. Since the activity of the impurity atom is low in the metal, the oxide must be much more stable thermodynamically than the oxides of the main components. In addition, the impurity atoms must have a high mobility.

The oxidation of a 2 percent beryllium copper alloy is a good example of the proper conditions existing for the impurity atoms to concentrate in the outer layer. Electron diffraction studies by Hickman[2] has shown the formation of BeO on the surface although Cu_2O probably was present in the body of the oxide.

The presence of BeO in the outer layer changes the conditions for the transport of copper ions through Cu_2O, since the partial pressure of oxygen at the BeO-Cu_2O interface is greatly reduced. However, beryllium ions can change the concentration of cation vacancies in Cu_2O by a solution process. This process would provide vacancies for copper ion diffusion and thus allow the Cu_2O film to grow. Beryllium ions in addition can diffuse through the oxide film through the vacancies formed by its solution or as an interstitial ion. Since diffusion of beryllium in beryllium oxide is a relatively slow process compared to the diffusion of copper in normal Cu_2O, the overall rate of reaction of the metal with oxygen would be lowered.

One unfavorable factor in the formation of segregated oxide layers is that these layers may have different expansion coefficients. Such a condition may be detrimental to oxidation performance based on cyclic tests or to oxidation under variable stress conditions.

Formation of Mixed Oxides or Spinels

When certain bivalent oxides such as NiO and CoO are reacted with trivalent oxides such as Cr_2O_3 and Fe_2O_3, a spinel is formed. These spinels are stable thermodynamically and since many minerals

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Abstract

An analysis is made of the role of impurities in the oxidation of metals. The various impurities are considered in terms of their effects on the physical and chemical structure of the oxide, oxide-metal interface and metal. Eight types of effects are discussed and where experimental data are available these data are used to illustrate the nature of the effect. The eight types of effects are: (1) formation of new oxide of impurity atoms in outer layer, (2) formation of mixed oxides or spinels, (3) formation of impurity atom oxide in inner layer, (4) change in conductivity of oxide film, (5) change in physical properties and adhesive properties of oxide and oxide-alloy interface, (6) formation of inclusions and other defects in the metal, (7) concentration of impurities at the grain boundaries of the metal and (8) surface oxide-impurity atom reaction with volatile reaction product.

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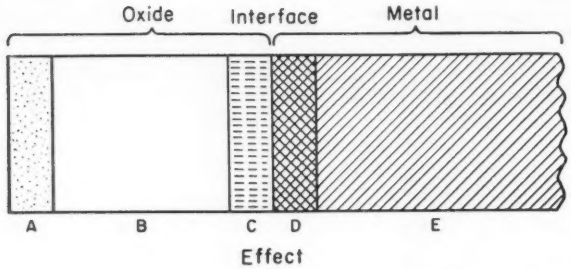


Figure 1—Effect of impurities on oxidation of metals. Steps are as follows: (1) Forms own oxide in outer layer of A, (2) Forms mixed oxides or spinels in A or B, (3) Forms own oxide in inner layers at C, (4) Substitutes in oxide B changing conductivity of oxide, (5) Concentrates in surface layer of metal at D or forms oxide at C changing physical and chemical properties of interface, (6) Forms inclusions and other defects in metal at D and E, (7) Concentrates at grain boundaries of metal at D and E, (8) Diffuses from metal to interface CD where reaction occurs forming volatile gas.

TABLE 1—Parameters of Chromites and Ferrites of a Number of Metals*

Divalent Metal	Atomic Number	Radius of Ion in Angstroms	Parameter of Oxide MO in Angstroms	Parameter of Chromite in Angstroms	Parameter of Ferrite in Angstroms
Nickel	28	0.74	4.1684	8.299	8.340
Magnesium	12	0.75	4.203	8.305	8.366
Cobalt	27	0.78	4.24	8.319	8.35
Iron	26	0.80	4.332**	8.344	8.374
Zinc	30	0.83	....	8.296	8.423
Copper	29	....	....	....	8.445
Manganese	25	0.83	4.4345	8.436	8.457
Cadmium	48	0.99	4.689	8.567	8.684
Calcium	20	1.05	4.797	....	....
Strontium	38	1.18	5.144	....	....
Barium	56	1.38	5.523	....	....

* Data taken from Reference 4.
** 50 atom percent Fe.

and oxides possess this structure, substitution of foreign metal atoms can occur without a large change in the lattice parameters. In view of the flexibility and stability of the spinel structure, Quarrell[3] has suggested that the oxidation resistance of heat-resisting steels is due to the formation of a stable spinel.

To show the flexibility of the spinel structure, Table 1 shows the lattice parameters of the known ferrites and chromites as a function of the ionic radii of the bivalent ion. Bénard[5] has suggested from a consideration of a similar table that the ferrites of nickel (II), magnesium, cobalt (II), and iron (II), having the spinel structure, form readily. He has suggested also that the ferrites of copper (II), and manganese (II) form incompletely and that the ferrites of calcium and barium do not form because of the size of the bivalent ion.

Although less information is available on the chromites, Table 1 suggests that chromites do not form readily with ions of atomic radii larger than that of cadmium (II) and a series of chromites is formed similar to the ferrites.

Several interesting conclusions can be drawn from this comparison. Nickel, chromium, manganese, and iron should form spinels and mixed spinels. Even though manganese and iron are present in minor amounts in the alloy, they can substitute in the spinel structure and thus appear in the oxide film.

Calcium and silicon, not being able to form spinels with chromic oxide and ferric oxide, may form their own oxides or silicates in the inner layer of the oxide. In this sense, calcium and silicon may have a major influence on the oxide and interface between the oxide and the alloy.

The formation of silicates may be expected from consideration of the phase diagrams of the oxides.[6]

The fact that silica concentrates in the inner layer can be inferred also from recent radiotracer studies of Lindner.[7] Lindner has shown that silicon ion does not diffuse in other oxides and that the formation of silicates can result only from the diffusion of the other metal ions into silica. The mechanism of such reactions is not understood.

The formation of randomly distributed crystallites of two or more oxides has one unfavorable aspect for good performance in cyclic temperature oxidation or for oxidation under variable stress conditions. This is the fact that the individual crystallites of oxide could have different expansion coefficients and local stresses could develop between crystals leading to spalling of the oxide.

Formation of Impurity Atom Oxide in Inner Layer

If one of the minor components diffuses with great difficulty through the oxide for reasons of size, charge, solubility, etc., segregation of the oxides of these elements may occur in contact with the alloy interface. This appears to be the case for such ions as silicon, calcium, etc. Since silica films are amorphous and silicate films may also be amorphous except after long periods of heating, the presence of these films would be difficult to detect by diffraction techniques. If sufficiently impervious, these films could control the rate of reaction. Thus, if the layer prevented metal ions from moving into the outer layer the reaction would be effectively stopped. Although the possibility for such a phenomenon exists, no proven example has been observed.

Change in Conductivity of Oxide Film

Wagner[8] and Hauffe and associates[9] have considered the influence of additions of metallic impurities on the conductivity and thus the rate of oxidation. If one accepts the Wagner theory of oxidation and also assumes that the mobilities of the disordered ions and electrons are not changed by the presence of foreign ions, then it is necessary to diminish the number of ionic defects in order to obtain a decrease in the rate of oxidation or to increase the concentration of ionic defects in order to increase the rate of oxidation. This is best understood by the application of the law of mass action to ionic and electronic defects in mixed crystals. Wagner and Hauffe have shown that the mass action law can be applied to: (1) Ionic conducting layers such as silver bromide, (2) Quasi-free electron conducting oxides such as zinc oxide, and (3) Electron hole conducting oxides such as NiO. To illustrate the effect of impurities the example considered will be the oxidation of nickel which involves an electron-hole conducting oxide NiO.

Wagner[10,11,12] derived the general formula of high temperature oxidation of metals under conditions for

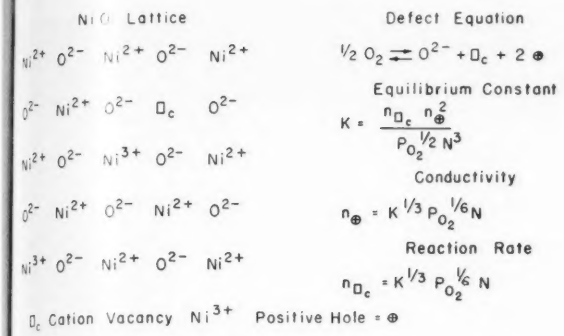

NiO Lattice
Ni2+ O2- Ni2+ O2- Ni2+
O2- Ni2+ O2- □c O2-
Ni2+ O2- Ni3+ O2- Ni2+
O2- Ni2+ O2- Ni2+ O2-
Ni3+ O2- Ni2+ O2- Ni2+
□c Cation Vacancy Ni3+ Positive Hole = ⊕
Defect Equation
½ O2 ⇌ O2- + □c + 2 ⊕
Equilibrium Constant
K = n□c n⊕2 / PO2 1/2 N3
Conductivity
n⊕ = K 1/3 PO2 1/6 N
Reaction Rate
n□c = K 1/3 PO2 1/6 N

Figure 2—Lattice defects in nickel oxide (vacancy type).

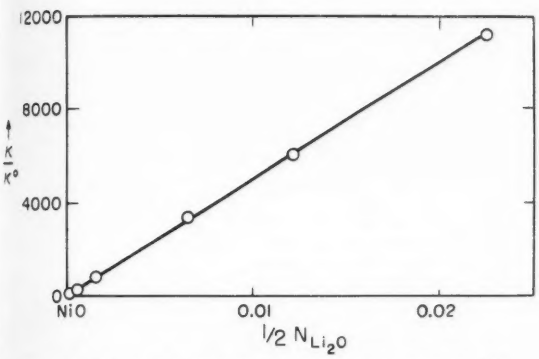


Figure 3—Effect of Li_2O on the electrical conductivity of NiO.

which the parabolic rate law of oxidation holds. The rate of oxidation is expressed in terms of the free energy of oxidation, the electrical conductivity and the transport numbers of the ions and electrons.

Figure 2 shows the type of lattice defects present in NiO in equilibrium with oxygen. According to the figure when one-half mole of oxygen goes into solution one cation vacancy is formed together with two positive holes and one oxygen ion. If it is assumed that no electrons are added or removed, the number of cation vacancies per cm^3 equals one-half the number of positive holes.

The equilibrium constant for the defect equation is:

$$k = \frac{n_{\square_c}}{N} \cdot \left(\frac{n_{\oplus}}{N}\right)^2 \cdot \frac{1}{p_{O_2}^{1/2}}$$

Here, N is the total number of sites per cm^3, p is the pressure of oxygen in atmospheres, n_c/N is the concentration of cation vacancies and $n_{\oplus}/N$ is the concentration of positive holes.

Since the rate of oxidation is proportional to the concentration of vacancies in NiO, the rate can be increased or decreased by the addition of an impurity metal whose oxide is soluble in the major oxide and which gives monovalent or trivalent cations respectively. If Li_2O oxide is present as an impurity, Li+ enters the crystal lattice according to the equation:

$$1/2O_2(g) + Li_2O(s) \rightleftharpoons 2\,Li_{\oplus}'(Ni) + 2\,\oplus + NiO(s)$$

Following the notations of Hauffe, $Li_{\oplus}'(Ni)$ represents a lithium ion in a nickel position and the ′, the negative charge of the impurity center. ⊕ represents an electron hole. The equation suggests that one electron hole ⊕ is obtained for each Li^+ substituted for Ni^{2+} in order to maintain electrical neutrality. Conductivity measurements of Verwey[13] and associates shown in Figure 3 confirm this effect.

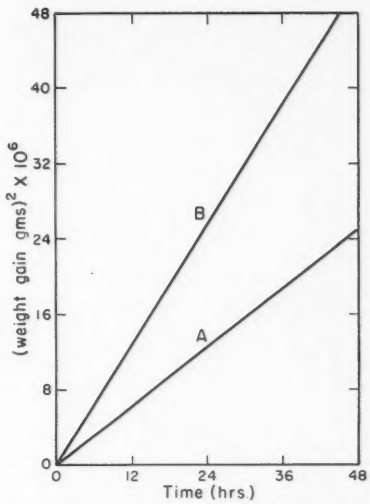


Figure 4—Effect of Li_2O on parabolic rate law constant, oxidation of Ni at 1100 C. Line B represents air and Line A is air plus impurity of Li_2O vapor.

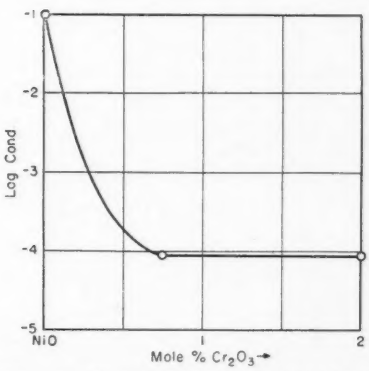


Figure 5—Effect of Cr_2O_3 on the electrical conductivity of NiO.

If equilibrium is to be maintained between the concentration of electron holes and cation vacancies, then the effect of increasing the number of electron holes is to decrease the number of nickel ion vacancies. Thus, the rate of oxidation of nickel is decreased by the addition of Li_2O. This has been experimentally studied by Hauffe and Pfeiffer[14] and the results shown in Figure 4.

If chromium oxide is dissolved in nickel oxide, the electrical conductivity is lowered. This is shown in Figure 5 which gives some recent results of Hauffe and Block.[15] According to Wagner's scheme which is illustrated in Figure 6 the solution of trivalent chromium ions leads to an increase in the concentration of nickel ion vacancies and to a decrease in the

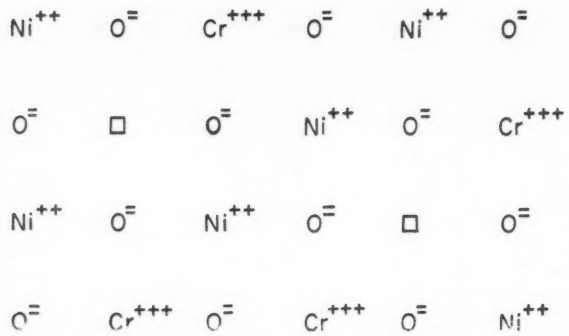
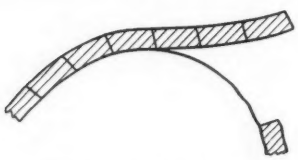


Figure 6—Lattice defects in a mixed $NiO\text{-}Cr_2O_3$ crystal.

A. BRITTLE CRACKING OF ADHERENT OXIDE



B. PEELING OF NON-ADHERENT OXIDE

Figure 7—Physical failures of oxide films.

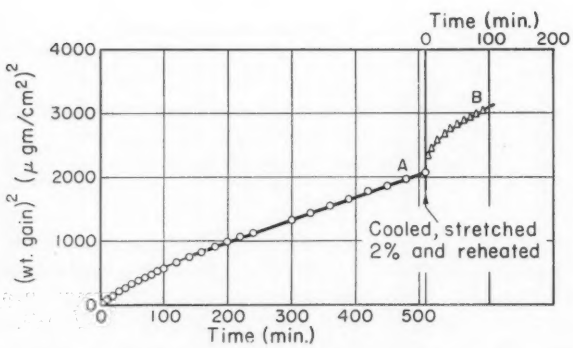


Figure 8—Effect of strain in oxide on the reoxidation of Ni-Cr alloy 493 (low Mn, low Si.) Guide to curves is as follows: A—900 C and 7.6 cm of Hg of O_2, $K = 5.73 \times 10^{-14}$ $(gm/cm^2)^2/sec$; B—900 C and 7.6 cm of Hg of O_2, after cooling, stretching 2 percent and reheating, $K = 9.81 \times 10^{-14}$ $(gm/cm^2)^2/sec$.

concentration of electrons. The equation for the solution of Cr_2O_3 in nickel oxide is:

$$Cr_2O_3 \rightleftharpoons 2\,Cr_{\oplus}\cdot(Ni) + Ni_{\square}'' + 3\,NiO$$

Here $Cr_{\oplus}\cdot(Ni)$ represents a chromium ion in a nickel ion site. One nickel ion vacancy $Ni_{\square}$ is formed for two chromium ions going into solution. Since the rate of oxidation depends upon the number of cation vacancies the rate of oxidation should increase with the chromium content until a new oxide phase is formed.

Table 2 shows the experimental results of Wagner

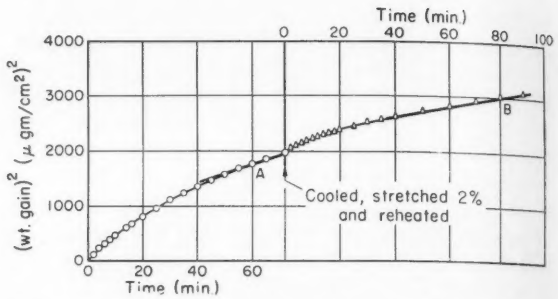


Figure 9—Effect of strain in oxide on the reoxidation of Ni-Cr alloy 495 (low Mn, high Si). Guide to curves is as follows: A—900 C and 7.6 cm of Hg of O_2, $K = 2.82 \times 10^{-13}$ $(gm/cm^2)^2/sec$; B—900 C and 7.6 cm of Hg of O_2, after cooling, stretching 2 percent and reheating, $K = 1.6 \times 10^{-13}$ $(gm/cm^2)^2/sec$.

TABLE 2—Rate of Oxidation of Nickel-Chromium Alloys at 1000 C*

Weight Percent Cr	t sec	Weight Gain gm/cm²	Parabolic Rate Law Constant $(gm/cm^2)^2/sec$.
....	57,600	4.1×10^{-3}	3.1×10^{-10}
0.3	57,600	8.8×10^{-3}	14.0×10^{-10}
1.0	57,600	12.3×10^{-3}	26.0×10^{-10}
3.0	57,600	13.4×10^{-3}	31.0×10^{-10}

* Data taken from Reference 16.

and Zimens[16] on the rate of oxidation of several nickel-chromium alloys at 1000 C.

Change in Physical Properties and Adhesive Properties of Oxide and Oxide-Alloy Interface

The minor components may concentrate in the surface layer of the alloy, as oxide in the oxide-alloy interface, or may form silica or silicate films and thus change the physical properties of the oxide-alloy interface or the bonding between the oxide and alloy. Thus, if minor components tend to embrittle the oxide, stresses set up between the oxide and metal may cause cracks within the oxide rather than between the oxide and the alloy. If the concentration of the minor components or their oxides tends to weaken the bonding between the oxide and metal, the oxide may scale in large sections. A third case, which leads to powdering of the oxide, will occur when a brittle oxide is formed that has poor adhesion to the alloy. This may be true where there is a segregation of oxide crystallites.

Figure 7 shows schematically the first two conditions. Thus an oxide which is embrittled for one reason or another, but possesses good bonding between the oxide and the alloy, may be more protective than a more flexible oxide with poor adhesion between the oxide and the alloy.

In addition to physical considerations, the concentration of minor components as oxides or as elements at the oxide-alloy interface may alter the reactivity of the grain boundary between the alloy crystals. This has been discussed in a micrographic study by Lustman[17] for the oxidation of nickel-chromium alloys.

The effect of strain on the rate of oxidation has been studied in a recent work of Gulbransen and

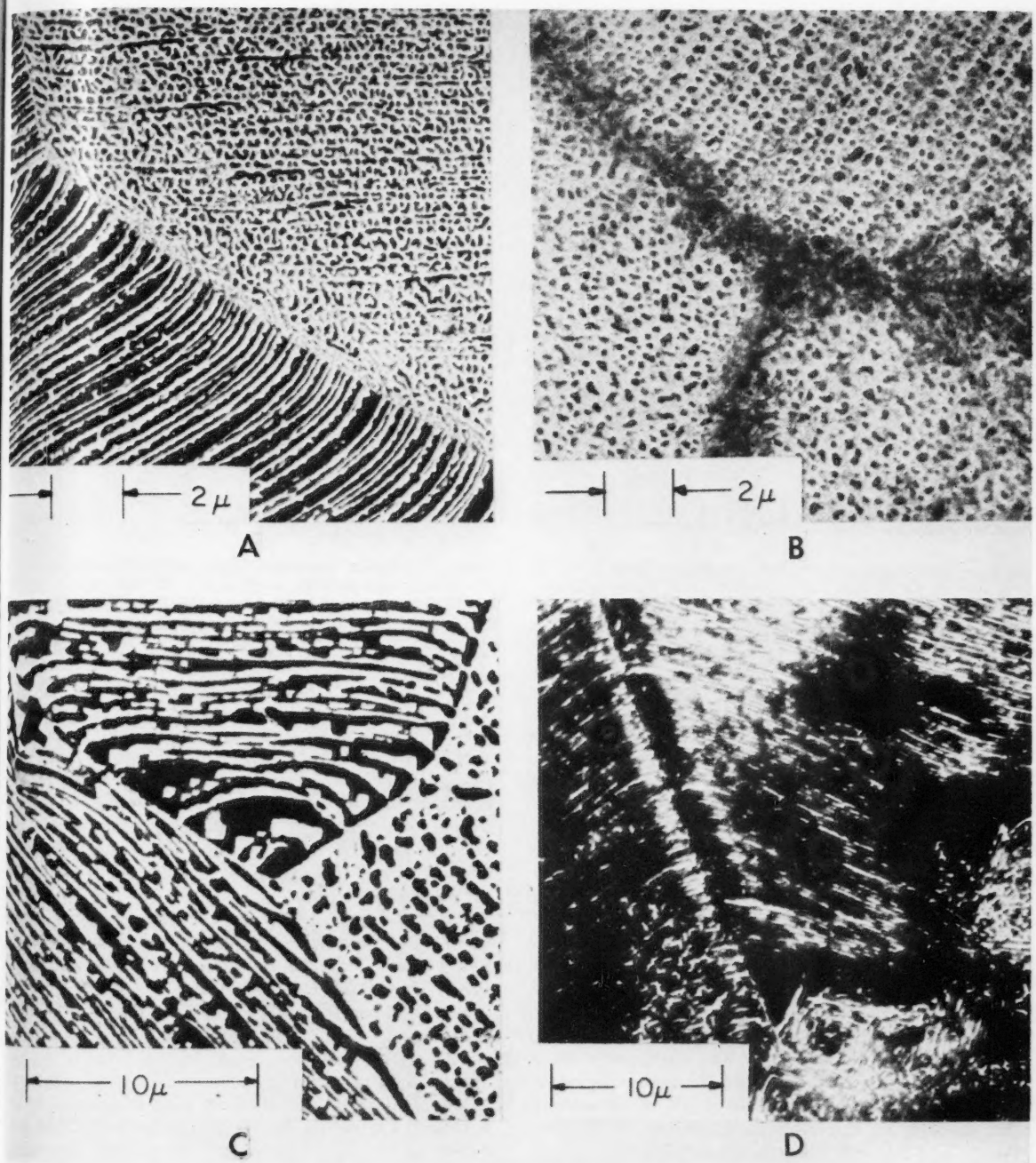


Figure 10—Low pressure oxidation of Puron. Code to photomicrographs is as follows: A—650 C, 1 × 10^{-3} mm Hg, 252 Angstroms average thickness; B—750 C, 1 × 10^{-3} mm Hg, 322 Angstroms average thickness; C—850 C, 2 × 10^{-3} mm Hg, 752 Angstroms average thickness; D—850 C, 1 × 10^{-2} mm Hg, 1174 Angstroms average thickness.

Andrew.[18] It may be determined by using a sensitive weight gain method in two ways. First, the effect of strain could be evaluated at an early stage in the reaction by observations on the rate of oxidation before and after application of stress. Second, the weight loss would be observed at a later stage in the oxidation reaction and thus measure the amount of spalling and flaking of the oxide. The first method was used in this work. Since the parabolic rate law constant is a sensitive measure of the rate of oxidation it is used to evaluate the effect of strain.

The experiments to be described were made to determine the effect of silicon on the adhesion of the oxide to the metal for the nickel chromium series of heater alloys. The strain was applied to the system of metal plus oxide after a certain initial oxidation had occurred.

Figures 8 and 9 show typical parabolic rate law

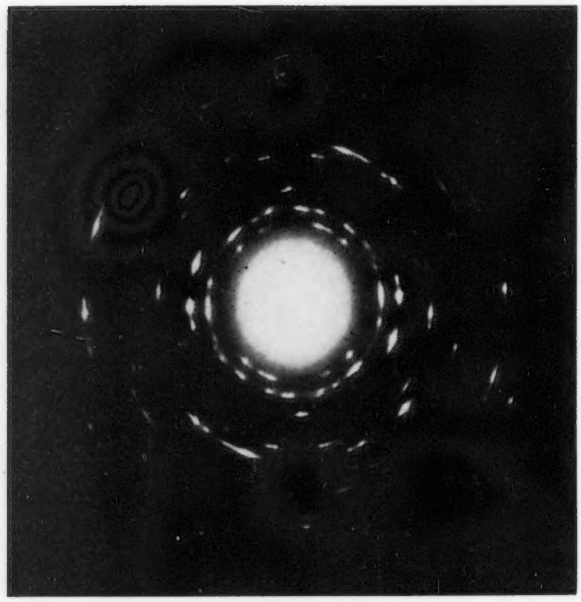


Figure 11—Electron diffraction pattern from oxide on Puron (at 850 C, 2×10^{-3} mm Hg).

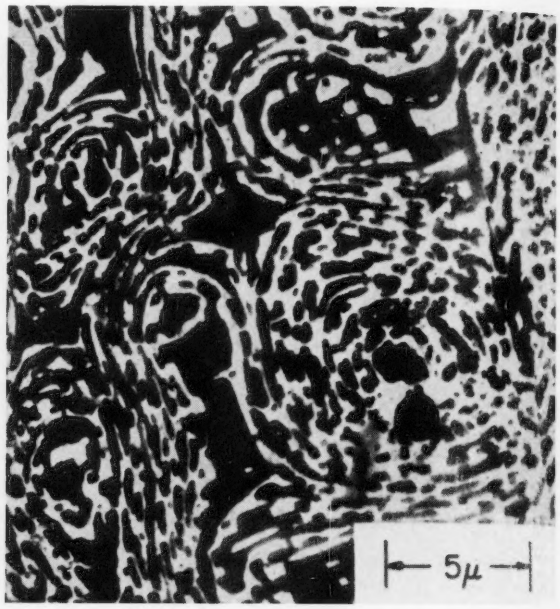


Figure 12—Electron micrograph showing circular growth patterns in oxide on Puron (at 850 C, 2×10^{-3} mm Hg).

plots of the effect of strain on the oxidation of a low and high silicon nickel chromium alloys 493 and 495 at 900 C. These alloys have a nominal composition of 80 percent nickel and 20 percent chromium with a calcium content of 0.03 to 0.04 percent. Figure 8 shows that for the low silicon alloy 493 a two percent stretching of the sample increased the parabolic rate law constant from a value of 5.73×10^{-14} (gm/cm^2)^2/sec to a value of 9.81×10^{-14} (gm/cm^2)^2/sec.

Figure 9 shows a similar study for the high silicon alloy 495. Stretching of the sample lowered the parabolic rate law constant from 2.82×10^{-13} (gm/cm^2)^2/sec to 1.6×10^{-13} (gm/cm^2)^2/sec.

It can be noticed in the figures that silicon increased the rate of oxidation at constant temperature. However, when the system is placed under strain, silicon improved the overall oxidation resistance. These experiments suggest that impurity elements such as silicon in the metal or alloy can greatly affect certain physical and chemical properties of the oxide and oxide-metal interface. These results show a direct correlation with the American Society of Testing Materials[19] useful life tests on heater alloys.

Formations of Inclusions and Other Defects in the Metal

Bardolle and Bénard[20] have shown that the oxidation of a well annealed polished sample of iron occurs in a discontinuous manner at high temperatures and at low oxygen pressures. Well-oriented oxide nuclei form at apparently random positions on the metal grain. Gulbransen, McMillan and Andrew[21,22] have modified their method and have applied the method to the study of the initial stages of oxidation. The conditions and extent of oxidation are carefully controlled and measured and electron optical methods used to study the finer details of the structures formed.

The study of Bardolle and Bénard[20] has suggested that some substructure in the metal grain is important in the nucleation and growth of oxide crystals. To study this, several progressive stages in the oxidation of Puron were studied with the metal specimen carefully polished and annealed in pure hydrogen.

Figure 10 shows electron micrographs of the electrochemically stripped oxide films which were formed on Puron at several temperatures and for varying amounts of oxidation. The essential oxidation data and the magnification are included in the captions to the figure.

Part A of Figure 10 shows the crystal size and habit associated with the formation of a thin oxide film at 650 C of 252 Angstroms average thickness. Parts B, C and D show electron micrographs for oxide films formed at 750 and 850 C having average thicknesses of 322, 508 and 1207 Angstroms respectively.

Figure 11 shows an electron diffraction pattern of the oxide formed at 850 C. A highly oriented oxide is found. Figure 12 shows the oxidation pattern surrounding inclusions probably of oxide in the metal. A circular growth pattern is observed.

An analysis of Figures 10, 11 and 12 leads to many interesting facts about the role of metal and its inclusions and defects on the process of nucleation and growth of oxide crystals. These findings may be summed up as follows:

(1) Single crystals of oxide do not form on a single grain of the metal. The fact that many oxide growth centers are observed on each grain may be related to the presence of defects and inclusions in the metal grain.

(2) For Puron annealed in dry hydrogen the oxide crystals form along certain directions of the metal grain with the crystal

habit determined by the orientation of the metal grain.

(3) Circular growth patterns probably are related to inclusions.

(4) The density of oxide growth centers is of the same order as the density of dislocations in a well annealed crystal of metal.

One can speculate that the nucleation and growth of oxide crystallites occurs at local defects in the metal structure and that these defects may be dislocations. The alignment of the growth centers in the figures may be due to the embrittling effect of hydrogen annealing processes.[22]

Concentration of Impurities at the Grain Boundaries of the Metal.

The grain boundary area of a metal presents an interface where impurity atoms may concentrate. Thus, the grain boundary area may present a lower activation energy for chemical attack than other areas in the crystal. The magnitude of the difference between grain boundary areas and the normal surface area is determined in part by the difference in orientation of the two adjacent grains.

Surface Oxide—Impurity Atom Reaction with Volatile Reaction Product

The reaction of carbon in the metal with the surface oxide to form carbon monoxide is an example of Type 8 shown in Figure 1. This reaction is found to occur above 600 C for iron[23] and above 800 C for 80 nickel-20 chromium alloys.[24] The kinetics of this reaction for nickel-chromium alloys has been studied by Gulbransen and Wysong[24] although a mechanism for the reaction has not been proven. It is readily seen that this reaction tends to destroy the oxide-metal interface, as well as having a strong effect on the physical properties of the metal or alloy.

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What Does Corrosion Really Cost?*

By W. B. HIRSCHMANN*

Introduction

CORROSION OCCURS so frequently and is associated with so many problems that there is a natural wonder as to its total cost to an organization. This wonder has a practical aspect: If the cost of corrosion is large, it follows that a large amount of effort or money may be justified for studies aimed at reducing such corrosion.

Inherent Difficulties

Actual determination of the cost of corrosion is not a simple straightforward job. There are a number of ramifications which can lead to confusion in measuring and interpretation. This confusion seems to relate primarily to what is meant by corrosion, and what is meant by cost. While corrosion is recognized to be the cause of one type of deterioration, its cost often is not clearly segregated from the cost of other types such as erosion, abrasion, creep, fatigue, carburization, scaling, stress-rupture, etc. That is, mitigation measures may be undertaken to handle one or a combination of these and other items.

Painting of a tank, for example, may be done for decoration or for decreasing vaporization loss as well as for controlling corrosion. Lack of recognition of such joint benefits resulting from one expenditure exaggerates the cost assigned to corrosion, and casts doubts on its validity. The best way to handle such joint benefits seems to be to allocate to each benefit a fair portion of the total cost. Such a formal recognition of the costs of these other items gives validity and credibility to the cost assigned to corrosion, and puts this cost of corrosion in proper perspective to the other costs and to the over-all needs of the organization. Corrosion is thereby defined not only by what it is, but also by what it is not.

Isolating the Cost of Corrosion

A possible classification of types of deterioration for the purpose of isolating the cost of corrosion is the following:

1. Corrosion failure.
2. Erosion and wear failure.
3. Heat failure.
4. Mechanical failure.
5. Non-metallic failure.
6. Others.

It sometimes is difficult to assign a failure to a single cause in a classification system. A furnace tube failure, for example, may result from overheating due to scale formation or coke deposition as well as to corrosion. Classification then becomes a matter of judgment. Therefore, it is essential that the classifying be done by people with sufficient background to use such technical judgment, and to use it consistently in all of the classifying.

It is unlikely that such a classification would be available from regular company accounting records, because normally there is no need to have such records kept on a continuing basis. More likely, it will be necessary to make a special survey. Such an investigation can most reasonably start with whatever cost records exist involving deterioration. These records then can be analyzed according to the above classification scheme.

In small plants or operations, a complete review of all such data is feasible. In large operations, the data are likely to be too voluminous for a 100 percent study. They can be analyzed, however, by a sampling technique. The sample may be one typical unit, or several units which are considered representative of the whole plant. Such an approach is suitable where cost records are kept by units. If they are kept by equipment components as pumps, compressors, vessels, etc., or by material as paints, inhibitors, neutralizing chemicals, etc., the sample can be a representative selection. In any case, the portion of the samples' deterioration costs that is due to corrosion can be applied to the whole organization or class of

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Abstract

Determination of the cost of corrosion is not a simple, straightforward job. A part of the problem depends on what is meant by corrosion and what is meant by cost. This paper is a guide for isolating the cost of corrosion. By also taking into account the effects of taxes and the time value of money, a measure is obtained of the cost of corrosion which is credible, and which is meaningful in relation to other costs and the net earnings of an organization.

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operation to which it is applicable to get its corresponding cost of corrosion.

The type and size of the sample will depend on the quantity and nature of data available, and the degree of reliability desired. In general, the larger the sample, the more precise the conclusions. It is unlikely that the "best" approach can be predetermined. More probably, it will be necessary to start this study along a reasonable line, and modify the plan according to needs as the survey progresses. It is obvious, however, that it is desirable to pay most attention to areas of large total deterioration cost where even small errors in estimating the percent of deterioration cost are important dollar-wise. Less attention should be paid to areas where the small total dollar deterioration cost makes it immaterial whether the percentage resulting from corrosion is 0 or 100 percent.

Such a review can be made of past records. It may be more meaningful and more reliable if done on current operations, because the conditions are recent enough to be recalled with reasonable precision and reflect current problems or needs.

Items or Areas Involving Corrosion

Some of the items involving corrosion which should be considered for economic analysis are the following:

1. Operating Costs
   a. Maintenance: Labor and materials for repairs; painting; inspection costs.
   b. Loss of product by downtime (scheduled and unscheduled), evaporation, leaks, contamination.
   c. Current for cathodic protection.
   d. Neutralizing or suppressing chemicals.
   e. Waste disposal (labor and materials).
   f. Filtration.
   g. Fires and other accidents.
   h. Above "normal" insurance rates.
2. Built-in Mitigation
   a. Alloys and metallizing.
   b. Corrosion allowance.
   c. Non-metals (porcelain, gunite, tar, plastics, wrappings).
   d. Cathodic protection.
   e. Dehydration equipment.
   f. Waste disposal equipment.
   g. Oversizing of units.
   h. Filter equipment.
   i. Tools and equipment for inspection and maintenance.
   j. Extra storage for tools and spare parts.

Net Cost of Corrosion

The suggested method of analysis will give a measure of the actual dollar cost of corrosion which still exists, and of the mitigating methods used to suppress the corrosion to its current level. In an economic analysis, however, it is necessary to distinguish between two kinds of dollars—those which can be expensed for tax purposes, and those which must be capitalized. Labor and materials for maintenance, for example, can be charged against current income. Such charges reduce income taxes. Without the maintenance expense, there would be operating income on which the company would be taxed, and as a result, it would be ahead only the net, after-tax portion. By virtue of the maintenance expense, the company is out of pocket only the net after-tax portion of the operating income. This decrease in net income is the effective cost of corrosion to the company. Mathematically, if E is the actual dollar cost of corrosion expense, and "t" the income tax rate, then:

$$\text{After-tax cost of corrosion expense} = E\,(1-t)$$

Sometimes, items which last more than a year can be expensed. Their cost needs to be spread over their life and expressed on an annual basis. This can be done by considering that the money spent for such corrosion mitigation deprives the company of profits which it could have had if the money had instead been put into an average plant operating investment. To be economically justified therefore, a corrosion investment must provide savings equivalent to the net operating profits foregone. The investment also must provide enough savings so that the item in question can be replaced when worn out. If, for example, a metallized lining with a life of four years is expensed, it must earn or save enough to pay for a new lining every four years, so that the corrosion protection program can be continuous, and in addition, earn on the money tied up the average rate of return on operating assets. These earnings or savings can be expressed on an equivalent annual basis as follows:

$$\text{Annual cost of expense items lasting more than one year}^1 = E_n\,(1-t)\frac{i\,(1+i)^n}{(1+i)^n-1}$$

where "E_n" is the cost (selling price) of an item lasting "n" years, and "i" is the after-tax earning rate required of money tied up in such items.

Built-in corrosion mitigating items, however, usually must be capitalized. All the money for them comes out of the company's treasury, because investment items cannot be charged against operating income to get a tax saving. However, their annual depreciation is an expense and can be so charged. They thereby provide an annual tax saving which is credited against the annual financial costs of recovering the capital invested and earning a profit.

If "I" is the number of dollars invested in corrosion mitigation, and "a" the amortization period in years over which the depreciation must be spread for tax purposes, then:

$$\text{Annual cost of corrosion mitigation investments}^1 = I\frac{i\,(1+i)^n}{(1+i)^n-1} - I\frac{t}{a}$$

The combination of the annual after-tax costs of the expensible and capitalized items gives the annual

net cost of corrosion to the company. For example, consider a firm whose income is taxed at the rate of $t = 50$ percent, whose after-tax earnings rate on net operating assets is $i = 10$ percent, and whose equipment is depreciated over an amortization period of $a = 25$ years. Suppose for example that a process stream has been causing an excessive corrosion downstream from its point of origin. It is proposed to neutralize this intermediate stream. The required mixing and metering equipment will cost $40,000 installed, and is expected to last 25 years and to be depreciated over 25 years. During its installation, the downtime lost is expected to amount to $60,000. The cost of the chemicals and of the operation of the equipment will run to approximately $200,000 per year. What will be the net annual cost of this corrosion mitigation treatment?

The equivalent annual after-tax cost of the $40,000 of capital equipment will be:

$$\$40{,}000 \times \frac{0.1 \times (1.10)^{25}}{(1.10)^{25} - 1} - 40{,}000 \times \frac{0.5}{25} = \$3607 \text{ per year}$$

The $60,000 cost of downtime can be charged against current income, but must be spread over the 25 year life of the installation. Its equivalent annual after-tax cost over 25 years will be:

$$\$60{,}000 \times .5 \times \frac{0.1 \times (1.10)^{25}}{(1.10)^{25} - 1} = \$3305 \text{ per year}$$

The annual after-tax cost of the expense of equipment operation and of materials will be:

$$\tfrac{1}{2} \times \$200{,}000 = \$100{,}000 \text{ per year}$$

These annual net costs of mitigation will total about $107,000 per year.

Note that the net out-of-pocket cost of corrosion is considerably less than the gross costs. This circumstance results because the expense items can be charged against income before taxes, so that in effect one-half of this cost is paid by the government in the form of reduced taxes. As a further illustration, if $100 of this company's gross corrosion expenditure consists of $50 for expense items, E, which last less than one year, of $25 for expense items, E_n, lasting an average of $n = 5$ years, and of $25 of capital investment items, I, which lasts $a = 25$ years, then the equivalent net annual out-of-pocket cost for this gross $100 of corrosion is about $31.50.

A cost of corrosion determined by following the procedure suggested herein will be realistic because it recognizes possible joint causes of costs and joint benefits from mitigation expenditures. And by being expressed on an after-tax basis, it becomes meaningful for evaluating its effect on the net earnings of the organization.

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Stress Corrosion Cracking Of Monel in Hydrofluoric Acid*

By H. R. COPSON and C. F. CHENG

Introduction

IN 1944 O. B. J. Fraser[1] discussed the stress corrosion cracking of high nickel alloys. It was known at that time that Monel was susceptible to stress corrosion cracking in hydrofluosilicic acid, and examples of this were included in the paper. The failures were similar to those of Case 1 which will be described later in the paper. It was thought, however, that Monel was resistant to such cracking in hydrofluoric acid. Furthermore it was thought that all stress corrosion cracking in Monel and high nickel alloys was intergranular. Transcrystalline cracking was thought to be confined to fatigue failures or other types of mechanical failures where corrosion was not involved.

It was unexpected, therefore, in 1948 to find "K" Monel bolts breaking in transgranular fashion in hydrofluoric acid vapor. The circumstances of this cracking are described under Case 2 later in the paper. The diagnosis that this was stress corrosion cracking was not confirmed until the cracking was reproduced in the laboratory[2] in 1949.

The key experiment in these tests was one in which an air stream was passed through a 52 percent solution of technical hydrofluoric acid and then directed against a "K" Monel bolt stretched in tension. The bolt passed through the arms of a metal block, and had been tightened with nuts to produce tensile loads which ranged from 88,000 to 152,000 psi in different tests. After one day, microexamination showed that transcrystalline cracking had started similar to that found in service (Case 2). It made little difference whether the "K" Monel was cold drawn, cold drawn and aged, or annealed and aged.

Shortly afterwards a somewhat more extensive laboratory investigation was undertaken to learn more about the nature of the cracking. In particular it was desired to determine: (1) The behavior of some other alloys, (2) The effect of impurities in the acid such as silicon tetrafluoride, and (3) The effect of minor constituents such as silicon in susceptible alloys. These tests are described in detail later on in the paper. Some of the work paralleled experiments conducted independently by Schussler.[3]

Once the general characteristics of this type of stress corrosion cracking were understood, it was realized that there had been earlier encounters with it. It is difficult to reconstruct these earlier situations, but Case 3 is an example. Some descriptions in the literature also are suggestive of this type of corrosion.[4]

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Abstract

It has been known for some time that Monel is susceptible to intergranular stress corrosion cracking in fluosilicic acid. It was surprising, however, to find "K" Monel bolts breaking in transgranular fashion in hydrofluoric acid vapor. The diagnosis that these failures were stress corrosion cracking was confirmed by reproduction of the cracking in the laboratory. Several similar case histories are reviewed and a number of qualitative laboratory experiments on the stress corrosion cracking of Monel and some other high nickel alloys in hydrofluoric acid environments are described. The number and path of the cracks is influenced by composition, cold work, heat treatment, stress, time and conditions of exposure. Cracking is most prone to occur where corrosion rates are high, such as in moist, aerated vapor. This suggests that hydrogen may play a part in the cracking. Means of avoiding the cracking are discussed.

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More recent examples have been easier to diagnose. Typical examples are given in Cases 4, 5 and 6. These case histories serve to outline conditions where the hazard of stress corrosion cracking of Monel is likely to exist. Actually Monel has a long record of excellent service in hydrofluoric acid environments and has been widely used.[5,6] It is hoped that the present paper will help to make this service performance even better. Some suggestions are made on how stress corrosion cracking may be avoided.

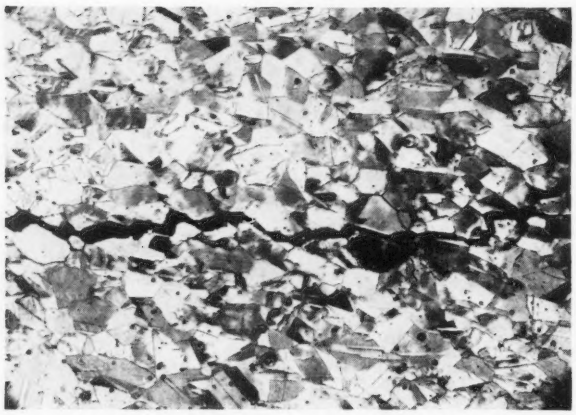

Figure 1—Intergranular crack in Monel tube exposed to 20-25 percent hydrofluosilicic acid at 120 F. Etchant: 10 grams CrO_3, 15 grams NH_4Cl, 30 ml HNO_3, 270 ml H_2O. 100X.

Figure 2—Cracking in "K" Monel bolt exposed to HF vapors. Copper was present in cracks before etching. Etchant: Carapella's Reagent. 500X.

Case Histories

Case 1

A 10-foot length of Monel tubing was used as a depth gauge in a storage tank containing 20 to 25 percent hydrofluosilicic acid at 120 F. After a time this tube split open over its entire length. The main crack was 0.02 inch wide. Using this figure, the wall thickness of 0.11 inch, and the outside diameter of 0.84 inch, calculations indicated that the circumferential internal stress had been about 31,000 psi.[7] The Monel was full hard, 96 Rockwell B. Microexamination showed that the cracking was intergranular. A typical branch crack is shown in Figure 1. The cracking might have started either in the vapor phase region or on the totally immersed portion.

Another piece of Monel tubing was used for conducting the same acid to a spray nozzle inside a spray chamber. The chamber contained air, water vapor, carbon dioxide, and vapors from the acid at 225 F. The Monel tubing cracked longitudinally in three to five months. It was not determined whether the cracking started from the solution side or the vapor side. The cracking was intergranular and appeared identical with that in Figure 1. The spray heads which were cast Monel showed no signs of cracking.

Case 2

Some 6 inch long, ¾ inch diameter, completely threaded, "K" Monel bolts were used to fasten the external flanged joints on pipe lines carrying anhydrous hydrogen fluoride at atmospheric temperature. When leaks occurred at the joints, the bolts were likely to break within 5 to 15 hours afterwards. No attempt was made to limit the stress set up in the bolts during installation, and undoubtedly the tensile stress was high.

Inspection showed that cracks had started at the root of every thread between the nuts, but no cracking was present under the nuts or at the unstressed ends. The bolts were covered with a copper flash showing that the escaping vapors had picked up moisture and caused corrosion.

In one instance[8] the bolts were hot rolled and aged, and had a hardness of 31 Rockwell C. Microexamination showed that the cracking was both intergranular and transgranular (see Figure 2). Before etching a copper deposit was present in the cracks.

In another instance[8] the bolts were cold drawn and aged, and had a hardness of 36 Rockwell C. In this case microexamination showed the cracking to be completely transcrystalline (see Figure 3).

Case 3

A small welded Monel tank, 10 x 8 x 5 inches in size, was used to hold 60 percent hydrofluoric acid. The acid was used for cleaning glass equipment. The tank was kept in a sink, which usually was wet with water. The Monel from which the tank was made was 0.06 inch thick and had been annealed (71 Rockwell B). Fabrication, of course, introduced stresses at corners and bends.

In time cracks developed at the corners about an inch from the bottom on the outside of the tank. There was practically no corrosion on the inside of the tank. Microexamination showed that these cracks were entirely transcrystalline.

Case 4

Monel pipe, 1.7 inch outside diameter and with 0.14 inch thick walls, was used to convey concentrated hydrofluoric acid from storage tanks on a hill outside the plant to the pickling department. In an area where the line passed through a concrete passageway under the floor, there were some poor welds and some leaking occurred. Within six months profuse longitudinal cracking had developed on the outside surface of the pipe in this portion of the line. There was no cracking in other parts of the line either indoors or outdoors.

Inspection showed that the cracks were very numerous with at least 50 deep ones to the inch and many smaller ones. Most of the deep cracks penetrated about half way through the wall. Microexamination showed that the cracking was completely transcrystalline. The cracks had a grey phase in them which was thought might be cuprous oxide. In some places metallic copper seemed to be present in the cracks. The Monel had a cold drawn structure.

Figure 3—Transcrystalline cracking in "K" Monel bolt exposed to HF vapors. Etchant: Carapella's Reagent. 250X.

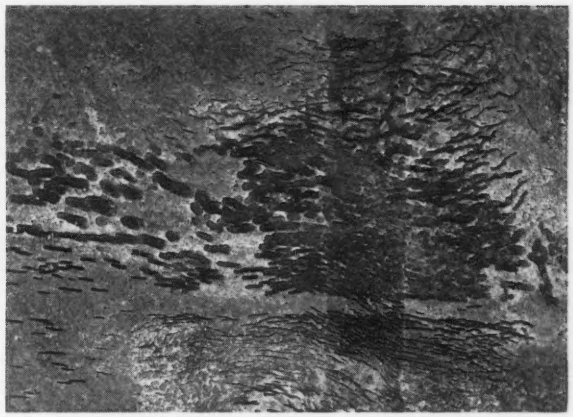

Figure 4—Striated attack on Monel exposed to HF vapors. Photo was made after 24 months operation. Unetched. ¾X.

elongated grains, and was full hard (206 VHN_5 pd). Undoubtedly the internal stresses were high.

Case 5

A Monel column, 3 feet in diameter and 18 feet high, was used for regenerating hydrogen fluoride. Anhydrous hydrogen fluoride was distilled off the top of the column, and a constant boiling mixture containing about 40 percent hydrofluoric acid was drawn off the bottom.

In the vapor phase region some areas of the column developed a striated or tree-bark appearance. This condition is illustrated in Figure 4, which shows the inside surface of the welded ⅜ inch thick plate. The attack was most severe in the portion of the column where presumably both moisture and air were very much in evidence. Very little corrosion occurred where the Monel was totally immersed in acid.

Microexamination showed that stress corrosion cracking had occurred locally with numerous parallel transcrystalline cracks. None of these cracks penetrated the Monel, their depth ranging from 0.01 to 0.13 inch. Some of the cracks were hairline, but most had been widened by corrosion to produce the striated effect. Two of the corroded cracks are shown in Figure 5.

The distribution of the attack indicated that it was associated with stresses in the column; two zones of attack were located diametrically opposite each other inside the column. The hardness of the Monel ranged from 65 Rockwell B to 93 Rockwell B.

Case 6

A corrosion test spool was placed in a fume scrubber. The gases contained air, carbon dioxide, water vapor, and fluorine volatiles at 160 to 220 F. The gas velocity was 60 ft/sec. The spray condensate was said to be under 2 percent acid. However, the conditions proved very corrosive, and many of the materials on the spool were lost within 52 days.

The Monel specimens corroded at a rate of 0.077 ipy. They developed cracks in and around the stencil marks which had been made for identification. Microexamination showed that the cracking was intergranular. The cracking seemed similar to that occurring in

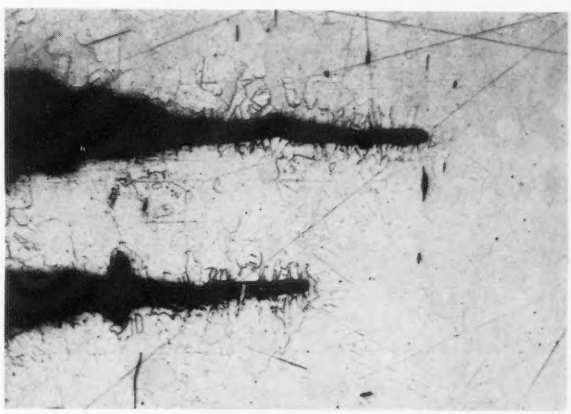

Figure 5—Transcrystalline cracks widened by corrosion. This produced striated appearance in Figure 4. Etchant: Persulfate-cyanide. 250X.

stressed Monel in other environments containing moist aerated hydrofluoric acid vapor. The association of the cracking with high corrosion rates is noteworthy.

Tests in Hydrofluoric Acid Vapor

The materials listed in Table 1 were made into U-bend specimens and exposed to hydrofluoric acid vapor. They were tested in softened, cold rolled, age-hardened, and welded conditions as indicated in Table 2. In addition two special compositions were tested. One was a Monel containing 1 percent silicon, and the other was an 85-15 nickel-copper alloy.

Machined pieces, 6 x ½ x ¼ inch in size with drilled holes near the ends, were used, except in a few instances where the specimens were wider or shorter as circumstances dictated. These pieces were bent over a 1½ inch rod in a tensile machine until the legs were about 2½ inches apart. Any age hardening treatments were carried out on these partially bent specimens. The U-bends were then completed by clamping the legs of the partially bent specimens in a vise and drawing up on the vise until the legs were nearly parallel. A Monel bolt, 3 inches long and ¼ inch in diameter was inserted through the drilled

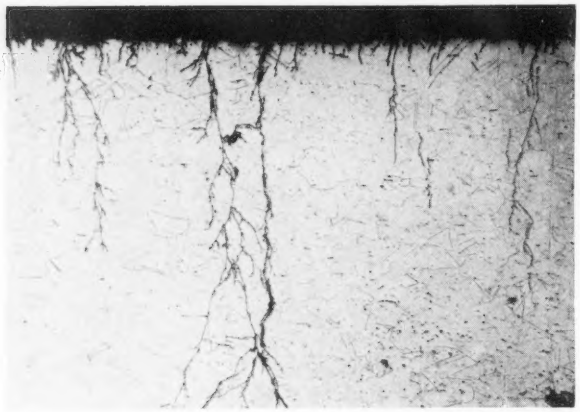

Figure 6—Tension side of hot rolled "K" Monel U-bend exposed to HF vapor. Etchant: Persulfate-cyanide. 100X.

Figure 7—Appearance of welded Monel U-bend after exposure to HF vapor. Unetched. 4X.

TABLE 1—Nominal Composition of Materials

	COMPOSITION, PERCENT									
Material	C	Ni	Cu	Si	Mn	Fe	Cr	Al	Ti	Cb
"K" Monel	0.15	66	29	0.50	0.75	0.9	...	2.75	0.5	...
Monel	0.15	67.0	30.0	0.1	1.0	1.4	...	...	...	...
Nickel	0.06	99.4	0.1	0.05	0.25	0.15	...	...	...	...
Duranickel	0.17	93.7	0.05	0.5	0.3	0.35	...	4.4	0.4	...
Inconel	0.08	77	0.2	0.25	0.25	7	15	...	...	...
Inconel "X"	0.04	73	0.05	0.4	0.5	7	15	0.9	2.5	1

holes, and Monel washers and nuts put on the bolt. The bolt was tightened until the U-bend test specimen came loose in the vise. The final leg separation was about 1½ inches.

The tests were carried out in 500 and 1000 ml polyethylene containers which had tightly fitting covers. About 200 to 400 ml of 48 percent CP hydrofluoric acid was placed in the bottom of the container. Anywhere from one to eight U-bend specimens were hung in the gas space above the acid on nickel or enamel coated copper wires passing through the the cover. The containers were then immersed approximately half way in a water bath at 140 F. Under these conditions the specimens were cooler than the acid and there was heavy condensation on the specimens.

There was some evaporation and loss of acid through the holes in the cover. Presumably there was also some air circulation through these holes. From time to time more acid was added as needed. The conditions in the gas phase were very corrosive although not particularly constant or reproducible. Monel specimens corroded at rates ranging from 100 to 1200 mdd. Corrosion products from the Monel bolts spread over the specimens with the formation of copper deposits. In addition the specimens became encrusted with green corrosion products.

The specimens were inspected from time to time for cracking and at the end of the tests they were cleaned by soaking in aerated 10 percent ammonia and scrubbing. After cleaning they were examined carefully under a binocular microscope. In any doubtful cases longitudinal cross sections were cut out, mounted, polished, and examined at high magnification.

Results on Monel

"K" Monel U-bends quickly developed a large number of closely spaced transcrystalline cracks penetrating deeply from the tension side of the U-bend. A typical result is shown in Figure 6. Hot rolled and age-hardened material behaved similarly. The aging treatment consisted of heating in hydrogen for 16 hours at 1100 F, and then cooling slowly to 900 F.

Regular Monel specimens cracked in much the same manner as "K" Monel. In cold rolled material

TABLE 2—Results on U-Bends in Hydrofluoric Acid Vapor

MATERIAL	Condition	HARDNESS		No. of Tests	First Observed Cracking Days
		VHN 30pd	Rockwell C		
"K" Monel	Hot Rolled	148–210	..	3	2 to 6
"K" Monel	Aged	.....	32	1	5
Monel	Annealed	109–136	..	23	4 to 15
Monel	Cold Rolled	250	..	2	6 to 15
Monel	Welded	.....	..	17	4 to 14
Monel + 1% Si	Cold Rolled	293	..	1	15
85 Ni, 15 Cu	Annealed	147	..	1	5
Nickel	Cold Rolled	232	..	1	14
Duranickel	Hot Rolled	204	13	1	None[a]
Duranickel	Cold Rolled	.....	28–29	2	49[b]
Duranickel	Aged	.....	37–41	6	4 to 9
Inconel	Cold Rolled	295	..	2	14 to 15
Inconel "X"	Hot Rolled	198	12	1	None[b]
Inconel "X"	Cold Rolled	.....	29–36	6	None[d]
Inconel "X"	Aged	.....	31–45	9	4

[a] 14 day test.
[b] Three other specimens were not cracked at 14 days when the tests were stopped.
[c] 49 day test; one other specimen was not cracked at 14 days when the test was stopped.
[d] Three 14 day and three 49 day tests.

the cracks were transcrystalline just as in Figure 6. In annealed material the attack was predominantly intergranular with many short transcrystalline branches. In many cases the cracks penetrated about half way through the specimens and then seemed to stop growing or to turn in a lengthwise direction. The large number of cracks may have relieved the stresses.

The cracking of a welded specimen is shown in Figure 7. Cracks developed in both the wrought metal and the weld metal. Tests were made on "130X" Monel welds with and without slag removal and also on inert gas shielded welds without any slag or filler, but no significant differences were noted.

A special Monel containing 1 percent silicon behaved like regular Monel. Similarly a high-nickel Monel, containing 85 percent nickel and 15 percent copper, cracked profusely. It can be concluded that silicon, nickel, and aluminum additions to monel have no major influence on susceptibility to cracking.

Results on Nickel

A cold rolled nickel specimen developed considerable intergranular attack and pitting. This tended to mask the cracking behavior, but the attack was deep on the tension side of the U-bend and shallow on the compression side. Cracks opened up in the tension side on additional bending.

Duranickel specimens likewise developed considerable intergranular attack and pitting. On hot rolled and cold rolled specimens the attack through 14 days was about the same on the tension side as on the compression side. There was no definite stress corrosion cracking at this time. After 49 days there was still no visible cracking, but microexamination revealed a few shallow transcrystalline cracks. These started on the ¼ x 6 inch surface.

Age-hardened Duranickel U-bends cracked rapidly in hydrofluoric acid vapor with some of the specimens breaking in two. There usually was just one main crack with some branch cracks. The cracking was intergranular as shown in Figure 8. The cracks always started on the outside of the U-bend, but in cold rolled and aged material the cracks tended to turn in the direction of rolling. In hot rolled and aged specimens the cracks continued straight across the specimens. This was the only difference noted between these two types of age-hardened material. The age-hardening was accomplished by heating at 980 to 1080 F in hydrogen for 16 hours, cooling at 15 F per hour down to 900 F, and then air cooling to room temperature.

Results on Inconel

Cold rolled Inconel specimens developed numerous shallow transcrystalline cracks on the tension side of the U-bends. The specimens showed considerable corrosion and pitting. Most of the cracks were widened by the corrosion, particularly beneath the surface.

On the other hand hot rolled and cold rolled Inconel "X" U-bends proved quite resistant to cracking. Through 14 days the attack on these specimens was rough and uneven but deep pitting and cracking were absent. However, by 49 days the corrosion had become somewhat intergranular and was accelerated and localized by the tensile stresses. In time this might lead to cracking. This effect was more noticeable on hot rolled than on cold rolled specimens.

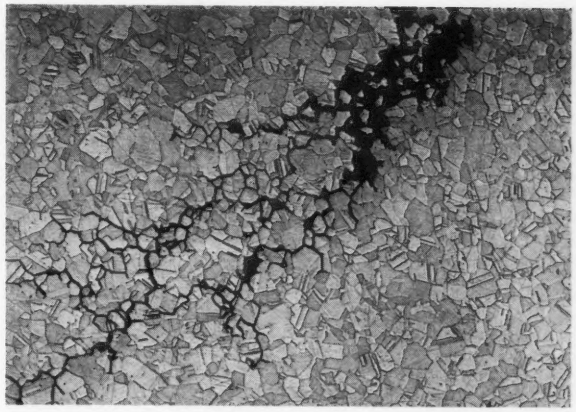

Figure 8—Intergranular cracking of hot rolled and aged Duranickel U-bend in HF vapor. Etchant: Persulfate-cyanide. 100X.

Age-hardened Inconel "X" U-bends cracked rapidly in intergranular fashion. The cracking was similar in all respects to that in age-hardened Duranickel specimens. The aging treatment consisted of heating in hydrogen at 1300 F for 20 hours and air cooling.

Tests in Hydrofluosilicic Acid Vapor

Several U-bend specimens of Monel and "K" Monel were exposed to the vapors above hydrofluosilicic acid. The method of testing was exactly the same as that in hydrofluoric acid vapor. The only difference was that the polyethylene containers held 30 percent CP hydrofluosilicic acid. The vapors would contain silicon tetrafluoride as well as hydrogen fluoride and moisture. Very likely the composition of the acid, vapor, and condensate changed somewhat during the tests as a consequence of the evaporation and loss.

The corrosion rates remained high in these tests although not as high as in pure hydrofluoric acid vapor. Cracking of the Monel and "K" Monel occurred as rapidly as before or possibly a little faster. The presence of hydrofluosilicic acid vapor was not a major factor in the cracking.

Total Immersion Tests

Several U-bend specimens of Monel and "K" Monel were totally immersed in 48 percent hydrofluoric acid, in 30 percent hydrofluosilicic acid, and in mixtures of these acids. The tests were carried out in covered polyethylene containers as before, so that while some air was present there was no vigorous aeration. Under these conditions the corrosion rates were low, of the order of 3 or 4 mdd. Some of the tests were carried on for 30 days, but there was no sign of any cracking. The absence of attack was confirmed by microexamination.

In two tests the acid was aerated vigorously by passing air through a plastic tube inserted in the acid.

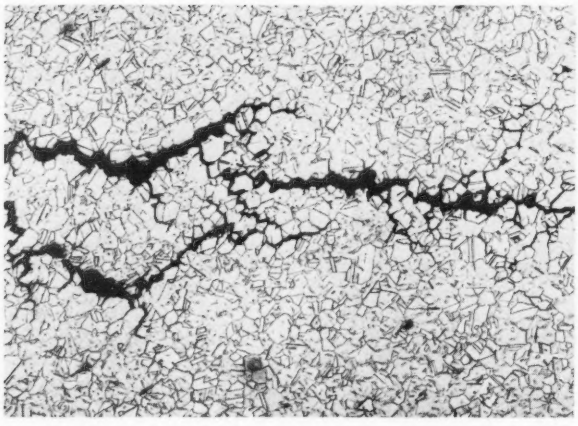

Figure 9—Intergranular cracking of age-hardened "K" Monel U-bend cathodically charged with hydrogen. Etchant: Presulfate-cyanide. 100X.

TABLE 3—Experiments With Monel U-Bends as Cathodes

MATERIAL	Condition	VHN 30pd	Rockwell C	No. of Tests	First Observed Cracking Days
"K" Monel	Hot Rolled	160	..	1	None[a]
"K" Monel	Aged	.....	34	3	5 to 16
Monel	Cold Rolled	242	..	1	None[a]

[a] 16 day tests.

Solution: 10% H_2SO_4 Current Density on Monel: 2.6 amp/sq dm
Temperature.....170 F Anodes: Platinum

The aeration greatly increased the corrosion. Some cracking was found in 15 days on "K" Monel U-bends totally immersed under these conditions. It might be argued that air bubbles impinging on the specimens produced vapor phase conditions. Nevertheless it seems probable that stress corrosion cracking can occur under total immersion conditions when the stresses are high and the corrosive conditions severe. Under the milder conditions normally encountered cracking seems to be absent.

Experiments With Monel U-Bends as Cathodes

The association of the cracking with high corrosion rates is unusual. It suggests that damage by occluded hydrogen may be involved. This possibility is supported by the fact that steels exposed to hydrofluoric acid environments have been known to blister, the hydrogen generated by corrosion entering the metal.[4]

A cathodic current applied to the specimen would be expected to distinguish between stress corrosion cracking associated with an electrochemical mechanism and that associated with hydrogen embrittlement. Cathodic protection should prevent the former type of cracking, but it would increase any influence of hydrogen. Unfortunately a cathodic current could not be applied to specimens exposed to hydrofluoric acid vapor under conditions where cracking normally would be rapid and profuse.

Some tests with a heavy cathodic current were carried out in an unrelated environment. This was 10 percent sulfuric acid at 170 F. Platinum anodes were used. The U-bends were half immersed, and a cathodic current of 2.6 amp/sq dm was applied. A separate jar was used for each test. The results are given in Table 3.

Nothing of any consequence happened to a hot rolled "K" Monel U-bend or to a cold rolled Monel U-bend in 16 days. However, the three hot rolled and age-hardened "K" Monel U-bends tested broke at the bends. The first specimen broke within five days and the other two within 16 days. No sign of any cracking was noticed until the specimens were completely broken in two. On the broken specimens, many branch cracks were present. Microexamination showed that this cracking was completely intergranular. Figure 9 illustrates the cracking.

Heavy cathodic currents such as used in these tests would lower the strength and ductility.[9] For example a cathodic current of 1 amp/sq dm for 14 days in 5 percent sulfuric acid at 150 to 160 F lowered the tensile strength of age-hardened "K" Monel rods 0.3 inch in diameter by 20 to 29 percent. It is thought that the cracking of the age-hardened "K" Monel U-bends during cathodic charging is related to this.

Owing to the fact that the cracking resulting from cathodic charging was entirely intergranular, it seems unlikely that the profuse transcrystalline cracking in hydrofluoric acid vapor can be attributed entirely to the effects of hydrogen. However, it is still possible that hydrogen embrittlement plays some part in the failures. There is considerable parallelism between the behavior of Duranickel and Inconel "X" in hydrofluoric acid vapor and the behavior of "K" Monel in Table 3. In hydrofluoric acid vapor, notches formed by corrosion would be expected to play an important role in the cracking. Experiments with tension type specimens should help clarify the relative importance of notches, applied loads and hydrogen embrittlement.

Means of Avoiding Cracking

One means of avoiding stress corrosion cracking is to eliminate the tensile stresses. With proper attention to design, applied loads usually can be kept low. Internal stresses can be relieved by a full anneal and slow cooling. However, a full anneal is not usually required. In the case of Monel, stress relieving by heating for one hour at 1100 F to 1200 F and slow cooling is recommended. In tests by O. B. J. Fraser[1] in 22 percent hydrofluosilicic acid at 149 F, cold drawn Monel tubing cracked in 328 hours, but stress relieving at 1000 F served to prevent the cracking.

Another means of avoiding stress corrosion cracking is to alter the environment. In the present case, cracking of Monel is most likely to occur when corrosion rates are high. Perhaps it is fortunate that non-ferrous metals such as Monel are normally specified only when they show good resistance to corrosion. In any case, making conditions less corrosive should be doubly beneficial by both avoiding the cracking and decreasing the weight losses. Exposure to moist aerated hydrofluoric acid vapor is the most dangerous condition. Avoiding the aeration and keeping the metal totally immersed are both beneficial. In one application continuous flushing with nitrogen has served to prevent the cracking.

Summary

Several case histories were presented which showed that Monel is susceptible to stress corrosion cracking in moist aerated hydrofluoric acid vapor. Laboratory tests reproduced the cracking in the vapor phase, and indicated that cracking was unlikely with total immersion. Age-hardened Duranickel and age-hardened Inconel "X" behaved similarly to Monel. Curiously these instances of stress corrosion cracking are most likely to occur when the corrosion rates are high. Both transcrystalline and intergranular cracking were observed. The mechanism is not certain, but it is suggested that hydrogen may play some part, particularly in the high strength materials. It was shown that age-hardened "K" Monel U-bends could be made to crack by cathodic charging with hydrogen.

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Any discussions of this article not published above will appear in the June, 1957 issue.

Discussions

Preventing Corrosion of Lead Sheathed Power Cables in Concrete Tunnels by R. I. Perry. *Corrosion*, Vol. 12, No. 5, 207t-212t (1956) May.

Question by John Edwin Johnson, Philadelphia Electric Company, Philadelphia, Pa.:

Why are the tunnels filled with water? It has occurred to me that since the water in the tunnel leached alkali from the concrete and thus created a corrosive solution, the corrosion could be prevented by removing the water. In Philadelphia there is a dry tunnel carrying fifteen 13 kv lead sheathed power cable lines and three 66 kv pipe type cable lines. The cables are in open trays and the pipes are also exposed. Any tendency for the cables or pipes to be corroded by solutions dripping on them can be observed and prevented by deflecting the drip with a baffle.

Reply by R. I. Perry:

The tunnels are filled with water to permit the maximum loading of conduits and to reduce the amount of sheath expansion due to migration of cable impregnating compounds. The load capability of the conduits would be reduced approximately 50 percent if the water were removed from the tunnels. In one tunnel containing 34 cables (consisting of 13 kv and 34.5 kv, 3-conductor cables and 69 kv, single-conductor cables), it was necessary to place cooling water in one end and pump water from the opposite end in order to carry the desired loads.

Question by W. H. Bruckner, University of Illinois, Urbana, Illinois:

Is any test made to determine the extent of cure of precast concrete duct before it is placed in the tunnel?

Reply by R. I. Perry:

Originally all precast concrete ducts were air-cured for 60 days before they were placed on the underground plant. Tests were made to determine the extent of cure. Present practice is to place all precast concrete duct after manufacture in a steam kiln for a minimum of 12 hours and to stockpile for a minimum of 90 days before using. The method of manufacture has not been changed and no tests have been made to determine the extent of cure of ducts placed on the underground plant at the present time.

High Temperature Hydrogen Sulfide Corrosion in Thermofor Catalytic Reformers. Publication 56-8. *Corrosion*, Vol. 12, No. 5, 235t-244t (1956) May.

Question by Walter L. Terrell, Jr., Baton Rouge, Louisiana:

Has any carburization of the straight chrome alloys been found in the Socony Mobil moving bed type units? Some carburization of recycle gas piping has been noted in both fluid and fixed bed units. Where this condition has been encountered, with one known exception, corrosion rates have been very low. This would seem to indicate that the conditions which will produce carburization will simultaneously reduce corrosion rates.

Reply by E. B. Backensto:

As far as we have been able to determine, no carburization has occurred.

Questions by M. G. Fontana, The Ohio State University, Columbus, Ohio:

I am glad to see these results. They confirm some pilot plant work I carried out about four years ago. The results at that time were somewhat puzzling because the low chromium steel (1 through 5 percent) showed higher rates of attack, in most cases, than ordinary carbon steel. I should like to ask the following questions:

1. Were any laboratory or pilot plant corrosion tests made before the first plant was designed and built? Some pilot plant process work must have been done before the process was adopted. Valuable data can be obtained at relatively little expense in the pilot plant or semi-works. This is an aspect frequently overlooked by process engineers.

2. Was any metallographic work done on the specimens particularly with regard to sub-surface attack? Our work showed both general and localized attack below the alloy surface and in many cases its penetration was greater than the general surface corrosion.

3. What do the corrosion rates represent? Do they refer to the completely consumed metal or do they include total (including sub-surface) penetration?

Replies by E. B. Backensto:

1. No laboratory or pilot plant corrosion tests were made before the first plant was designed. Our pilot plant equipment was constructed of 18-8 stainless steel and no unusual corrosion problem was anticipated. For the commercial units, materials were selected in line with our practices for handling high sulfur stocks; low chromium steels were selected for protection against hydrogen attack above 500 F.

2. Some metallographic work was done on test specimens, but sub-surface attack did not appear to be a major problem. We did find evidence of surface microfissuring on some carbon steels and low chromium steels when exposed in commercial units for seven months, but not in all cases.

3. The corrosion rates were calculated from weight loss measurements. The cleaning procedure is described in the text of the paper. The procedure used gave no significant weight loss on new, unexposed specimens.

Corrosion Mitigation in a Metropolitan Area by M. C. Miller. *Corrosion*, Vol. 12, No. 5, 247t-253t (1956) May.

Comment by S. A. Flemister, Southern Bell Telephone and Telegraph Company, Atlanta, Ga.:

We believe Mr. Miller has prepared an exceptionally fine paper which should prove helpful in assisting other cities to solve corrosion problems which might be similar. However, there are a few items mentioned in the paper which, in our opinion, deserve some clarification.

The paper states that the Southern Bell Telephone and Telegraph Company was using a small amount of forced drainage current from central-station batteries. This was not the case in this area. Since common grounding is employed in all Telephone Company central offices the use of central office batteries as a source of cathodic protection current would necessarily make other subsurface structures anodic with respect to that particular current. This practice has long since been abandoned.

The paper further states that there is no practical method of determining what percentage of the total rectifier current out-put is collected by each system. The Telephone Company isolated all of its underground cables from other structures and all bonds to the protection network were calibrated so a reasonably accurate measurement could be obtained of the current collected by the cables. The initial survey indicated that the telephone cables were using less than 10 percent of the total 500 amperes. Rather than resort to a complicated interbilling arrangement the Telephone Company volunteered to, and did purchase one of the first ten rectifiers installed.

In general, we are in complete agreement with the method used to alleviate the severe corrosion problem in Miami. We appreciate that Mr. Miller conceived the overall plan and wish to give him the full credit which he rightly deserves. However, we feel that the clarifications mentioned above might tend to eliminate some misinterpretations that could be obtained from the paper as it is published.

Inhibiting Corrosion of Steel, Aluminum and Magnesium Intermittently Exposed to Brines by George E. Best and John W. McGrew. *Corrosion*, Vol. 12, No. 6, 286t-292t (1956) June.

Question by F. N. Alquist, Midland, Michigan:

Please explain changes in chromate concentration used to decrease brine corrosion in tests discussed in paper. The starting concentration of chromate in the brine was x; after test the concentration was x-a.

Reply by George E. Best:

Rather than allow changes in hexavalent chromium concentration which would have represented a varying condition of test, regular additions of inhibitor were made so that only minor variations in concentration occurred. "Consumption" of inhibitor was based on the amount added which in turn was determined by hexavalent chromium analysis. The amount "consumed" must have been reduced to trivalent chromium, either as coating on the specimen or as precipitated hydrous chromic oxide. In some instances the latter was visible.

Question by H. Howard Bennett, Socony Mobil Oil Company, Inc., Paulsboro, New Jersey:

1. Has any work been done in which the specimens were washed with fresh water during the cycle?

2. The table showing dichromate consumption indicates increased inhibitor consumption with increased concentration. Is it not possible that the increase in chloride content was responsible for the increased inhibitor consumption?

Replies by George E. Best:

1. No experiments were made in the course of this program where the specimens were washed with fresh water as part of the exposure cycle.

2. Increasing chloride concentration is believed to be a factor in increasing bichromate consumption (Figure 7) but, from comparison with data on chromate, presumably decreasing pH level is of greater significance.

The Effect of Purification of Commercial Sulfonates on Their Corrosion-Stain Property by Harry C. Muffley, Van Hong and David Bootzin. *Corrosion*, Vol. 12, No. 8, 411t-414t (1956) August.

Comment by S. L. Chisholm, U. S. Naval Air Station, San Diego, California:

The corrosion-stain properties of petroleum sulfonates used in preservative oils have been studied at the Naval Air Station, North Island, San Diego, because such oils have been employed for more than 15 years for the internal protection of the engines of military aircraft. Quite a wide variety of sulfonates have been so employed, but due to the rather extensive qualification tests required by the controlling specification (e.g., Air Force-Navy Specification AN-C-576), staining usually is not observed to any significant extent when the concentration of sulfonate in oil is within the normal range of about 3 to 5 percent. An exception to this occurs with the indium lead bearing surfaces, which are very susceptible to such staining.

At higher concentrations a considerable variation

in staining of steel surfaces occurs. This is readily observed by coating garnet blasted steel panels with the sulfonates alone dissolved in a volatile solvent, such as toluene and exposing them in a humidity cabinet. Under these conditions if the coating is that of the same sulfonate extracted in warm isopropanol, no staining occurs. The minor part of the original sulfonate rejected by such extraction is found to be readily dispersible in warm water to a colloidal solution, is normally alkaline in reaction, and is definitely corrosive to steel.

A major part of the studies performed has been on a large sample of Shell Oil Sulfonate 60, kindly donated for this purpose. This sample had the stated composition of about 60 percent RSO_3Na, with an average equivalent weight of 470, about 4 percent water, 35 percent residual unsulfonated oil, and 0.6 percent of inorganic salts, chiefly sodium sulfate.

Discussions to technical articles appear in the June and December issues only when they do not immediately follow the article to which they pertain. Discussions received from December through May will appear in the June issue and those from June through November in the December issue.

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5.2.1-56 CORROSION CONTROL OF STEEL EQUIPMENT. T. R. B. Watson. **Can. Chem. Processing, 37**, No. 10, 46, 48, 50, 52, 54 (1953) Sept.

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5.2.1-57 CATHODIC PROTECTION LICKS CORROSION. L. C. Werkin. **Petroleum Refiner, 31**, No. 9, 122-124 (1952) Oct.

Cathodic protection, a positive, controllable and inexpensive method of preventing corrosion. There is real money in reducing these losses caused by corrosion-maintenance, replacement costs, over-design of equipment, and product losses. Refinery management and technical personnel must be keenly aware of the creeping inroads of corrosion, and alert to any feasible solution to the problem. Table showing cost estimates and savings resulting from its use on a large open-box-type refinery condenser and a large diameter Dorr clarifier. 9 refs.

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CORROSION ABSTRACTS

As Published in

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* The following designations apply to the several groups listed under 8. INDUSTRIES:

1. Air conditioning, architecture and building, refrigeration, sewage and water.
2. Communications, power.
3. Agriculture, beverage, dairy, fermentation, food, sugar, starch.
4. Fuel, solids; fuel, gases; petroleum refining and production, rubber, atomic energy.
5. Ceramics, glass, pulp and paper, wood products.
6. Laundry soap and detergents, textiles.
7. Graphic arts, instruments, jewelry, photography.
8. Chemical manufacturing, distilled liquor, electroplating, leather and tanning, metal fabrication and finishing, pharmaceuticals.
9. Aircraft, automotive, pipe line, railroad, shipping.
10. Explosives, metallurgy, mining ordnance and war materials, other.

Errata—Volume 12, 1956

Inhibition of Metallic Corrosion in Aqueous Media by Harry C. Gatos. Corrosion, Vol. 12, No. 1, 23t-32t (1956) Jan.

Page 28t, column 2, third and fourth lines of fourth paragraph should read:

types of inhibitors. For that reason
no particular importance should be

High Temperature Hydrogen Sulfide Corrosion in Thermofor Catalytic Reformers. Publication 56-8. Corrosion, Vol. 12, No. 5, 235t-244t (1956) May.

Page 237t, right hand column, line 11 should read:

in the corrosion rate results within the group of 0-9

Page 239t, left hand column, line 3 of last paragraph should read:

groupings, corresponding to 0-5 percent chromium

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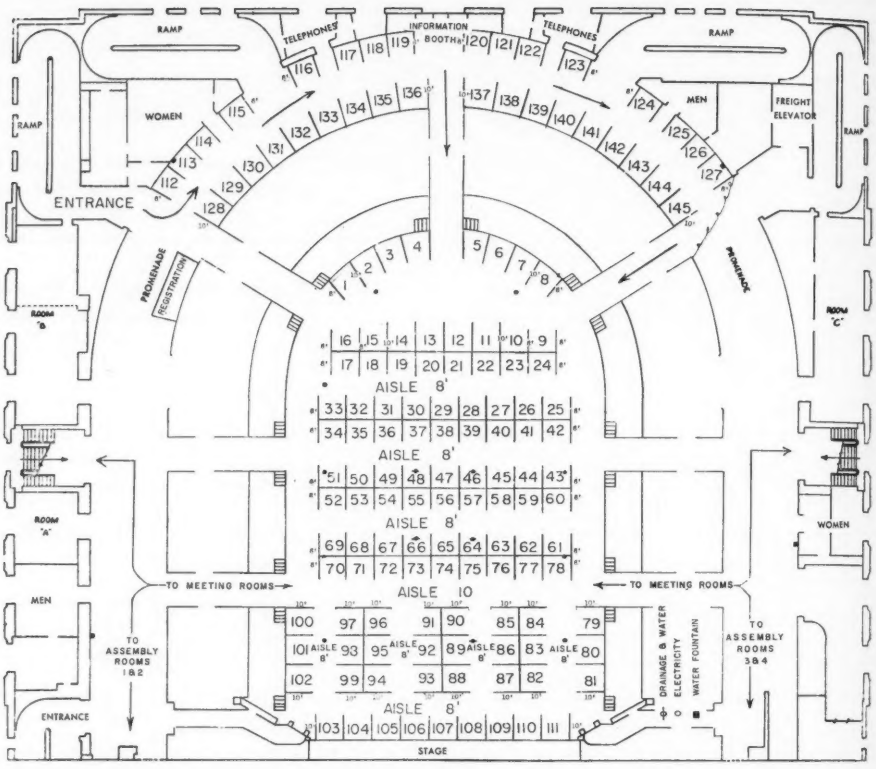

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VOLUME 12

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Offshore Structure Corrosion Rates Examined

Cost of Protection, Rates of Damage Data Are Reported

Over 75 members and guests heard reports on Offshore Corrosion Costs and Splash Zone Corrosion Rates on Steel Offshore Platforms at the meeting of Unit Committee T-1M held in San Antonio in October.

The task group on costs estimated the maintenance corrosion control cost per year on a tender-type platform to be $4000 to $8000; on a two-jacket self-contained platform $8000 to $12,000; on a three-jacket self-contained platform $12,000 to $40,000; and on drilling tenders $20,000 to $40,000.

Cost Data Are Given

Unit Costs for applying protection to platforms was estimated to be; (for applications on on-shore 40 to 80 cents per sq. ft. for vinyl or similar type coatings; 40 to 55 cents per sq. ft. for zinc coating; 25 to 40 cents per sq. ft. for bituminous coatings (no sandblasting); 50 to 70 cents per sq. ft. for galvanizing; 95 cents per sq. ft. for metallizing; $4 to $7 per sq. ft. for welded Monel sheathing; $5.60 per sq. ft. for ¼-inch wrought iron sheathing and $8 per sq. ft. for ¾-inch steel sheathing. For offshore applications; $4 to $20 per sq. ft. to sandblast and coat spray zone and 65 cents to $2 per sq. ft. to sandblast and coat superstructure.

A representative of a major oil producing company with extensive activity offshore presented the following report on splash zone corrosion rates.

Report on Splash Zone

The splash zone is the "middle man" on an offshore platform. It stands between the submerged zone, that portion which is always wet and the superstructure, the part which is usually dry. The splash zone is in an area which cannot be protected economically by cathodic protection below the water or by protective coatings above water. Its lower limit is usually placed at 1 to 2 feet below the mean water level and its upper limit at 5 to 8 feet above the mean water level.

Almost all offshore oil operators in the Gulf of Mexico protect their steel platform splash zones with metal jackets. Some install a protective barrier of 20 to 16-guage Monel sheet welded over platform members during initial fabrication. Others install no corrosion protection, but furnish corrosion allowance in the form of welded-on steel "doubler plates." The design life of these platforms runs as high as fifty years.

Those who use steel "doubler plates" have been hampered by a lack of adequate data on splash zone corrosion rates on steel offshore platforms in the Gulf of Mexico. The amount of extra steel used must be based on maximum rather than average corrosion rates because penetration to platform template legs cannot be tolerated. Exterior members also are exposed to abrasion by boats and barges. This accelerates corrosion in the frequently rubbed area.

Corrosion Rates Studied

To establish realistic corrosion allowance design rates actual metal loss was measured on four steel platforms, 5.6 to 7.2 years old. The study led to conclusions that total steel thickness in the splash zone (template leg plus "doubler plate") should be based on a maximum

(Continued on Page 98)

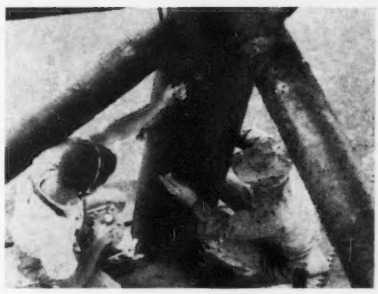


Figure 1—Top: Spots have been cleaned on template leg at elevations 5, 7 and 9 feet above mean Gulf level by chipping, wire brushing and filing. Supersonic gauge is measuring wall thickness at 7 feet above mean Gulf level. Bottom: After measurement, abraded spots are recoated and wrapped with tape.

TECHNICAL COMMITTEE SESSIONS at San Antonio (pictured below) during the October meeting of South Central Region featured standing room only. Views at some sessions, left to right: (First) Presiding at a meeting of T-2J on Wrappings for Pipe Line Coatings were Ivan L. Brunkow, Tulsa Pipe Coating Co., Tulsa, Oklahoma, acting secretary and Clark A. Bailey, Johns Manville Corp., New York, chairman; (Second) Otto H. Fenner, Monsanto Chemical Co., St. Louis speaks at a meeting of Unit Committee T-5D on Plastic Materials of Construction; (Third) Ivy M. Parker, Plantation Pipe Line Co. presides at a meeting of T-2E on Internal Corrosion of Products Pipe Lines and Tanks; (Fourth) left to right, C. G. Munger, Amercoat Corp., Southgate, Cal., vice-chairman; R. McFarland, Jr., Hills-McCanna Co., Chicago, chairman and John I. Richardson, Amercoat Corp., Southgate, Cal., acting secretary, at a meeting of T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion.

MORE VIEWS AT SAN ANTONIO TECHNICAL MEETINGS: (First) D. R. Fincher, Tidewater Oil Co., Alvin, Texas, chairman of T-1B on Condensate Well Corrosion and W. F. Oxford, Jr., Sun Oil Co., Beaumont, chairman of Group Committee T-1; (Second) R. M. Wainwright, Good-All Electric Mfg. Co., Ogallala, Neb. presiding at a meeting of T-2C on Minimum Current Requirements; (Third) C. P. Dillon, Carbide and Carbon Chemicals Co., Texas City, Texas, and W. W. Wheeler, Rohm and Haas, Houston respectively chairman and secretary of T-5C-1 on Corrosion by Cooling Water, South Central Region.

Offshore Structures–

(Continued From Page 97)

penetration rate of 20 mils per year. The "doubler plate" itself should furnish a corrosion allowance of at least 15 mils per year to guarantee adequate platform strength at the end of the design period.

Corrosion rates were measured by a supersonic gauge* One of the platforms was located about 10 miles from San Luis Pass, Texas and three were about the same distance from Grand Isle, Louisiana. Water depths were 40 to 50 feet.

* Audigage, Branson Ultrasonic Corp., 37 Brown House Road, Stamford, Conn.

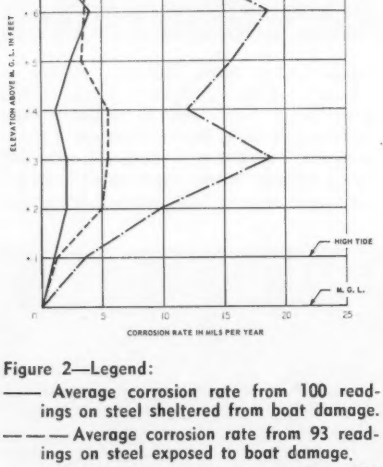


Figure 2—Legend:
—— Average corrosion rate from 100 readings on steel sheltered from boat damage.
— — — Average corrosion rate from 93 readings on steel exposed to boat damage.
—.—.— Maximum corrosion rates from 193 readings.
Platforms are assumed to have no corrosion at elevation 0.

On each platform checked, the procedure was approximately the same. A contract paint crew hand-chipped and wire brushed stipulated areas about four inches in diameter on template legs. A small spot one inch in diameter in the center of each four-inch area was then filed smooth without removing base metal. The gauge measurements were taken on the filed spots. Figure 1 illustrates the procedure used.

Remaining metal thickness was determined at 193 spots on template legs between one and nine feet above mean water level. These were divided between 100 spots on surfaces sheltered from boat damage and 93 spots on surfaces exposed to boat damage. Original metal thickness was determined from readings on spots where the original pipe line enamel coating was intact. Corrosion rates were calculated by dividing the metal loss by the age of the platform.

Data Are Plotted

Table 1 and Figure 2 show the results of the surveys. The two left hand curves in Figure 2 are average corrosion rates, one on the sheltered and one on the exposed steel. These serve only to show the relative effectiveness of the coatings used in preventing corrosion on sheltered and exposed legs. The right hand curve is plotted from the corrosion rate for the most corroded spot on each foot of elevation. This is the curve which shows when penetration will occur. No deep, sharp pits, were found, and, except at nine feet above the mean water level, the worst corrosion was found where substantial boat damage had occurred on exterior legs.

In general, average corrosion rates were 1-3 mills per year on sheltered legs and 3-6 mils on legs exposed to boat damaged. Maximum rates ranged from 10 to 20 mils per year in areas higher than one foot above mean water level. Maximum corrosion at elevation one foot above mean water level was only 3.6 mils per year, indicating partially effective cathodic protection up to that point. Platforms were assumed to have no corrosion at mean water level.

No special attempt was made to determine accuracy of the supersonic gauge on the first two platforms checked. On the last two platforms checked accuracy was calculated to be plus or minus 1.0 percent. This accuracy was determined by taking check readings five times during the work on a piece of ⅜-inch wall 16-inch outside diameter pipe whose exact wall thickness had been measured by a micrometer caliper. The last two platforms accounted for two-thirds of all the readings taken.

Steel Founders to Meet

The Twelfth Technical and Operating Conference Steel Founders' Society of America will be held November 11-13, 1957 at the Carter Hotel, Cleveland.

TABLE 1—Corrosion Rates on Four Offshore Platforms

	Surfaces Sheltered From Boats			Surfaces Exposed to Boats		
		Corrosion Rate In Mils/year			Corrosion Rate In Mils/year	
Elev. Above MWL	Number of Measurements	Avg.	Max.	Number of Measurements	Avg.	Max.
Platform A	(Age 7.2 Years)					
9	7	5.9	16.8	1	13.6	13.6
6	7	4.3	10.1	1	6.3	6.3
3	6	3.2	10.1	3	6.3	6.3
Platform B	(Age 7.0 Years)					
6	8	5.8	10.6	6	2.0	7.6
4	3	0.1	1.0	3	7.9	12.0
2	12	2.2	6.8	9	6.3	9.9
Platform C	(Age 6.4 Years)					
8	6	0.9	4.1	8	4.2	9.2
6	7	1.5	5.5	9	4.4	18.6
4	7	1.6	4.7	7	4.5	7.3
2	6	1.9	6.6	8	3.5	7.3
Platform D	(Age 5.6 Years)					
9	7	3.7	8.8	8	5.3	13.4
7	8	1.0	7.9	7	3.6	11.1
5	8	2.4	8.8	7	3.3	15.7
3	8	1.2	3.2	8	5.2	18.9
1	..	....	....	8	1.2	3.6
All Four Platforms:						
9	14	4.8	16.8	9	6.2	13.6
8	6	0.9	4.1	8	4.2	9.2
7	8	1.0	7.9	7	3.6	11.1
6	22	4.0	10.6	16	3.6	18.6
5	8	2.4	8.8	7	3.3	15.7
4	10	1.2	4.7	10	5.5	12.0
3	14	2.1	10.1	11	5.5	18.9
2	18	2.1	6.8	17	5.0	9.9
1	..	....	....	8	1.2	3.9

Numbering System Proposed to Facilitate Identification of Plastic Materials

Task Group T-5D-7 on Engineering Design of Plastic Materials of Construction presented a draft of the proposed T-5D Type Numbering System for the identification of plastic materials of construction at the T-5D meeting in San Antonio. The system is a modification of the system used to classify books in libraries and gives a method of expansion which will permit the incorporation of new plastics as well as modifications and combinations of existing plastics.

The report outlined the first step in an attempt to provide a system covering a means of standardization and providing for uniform specifications for all plastics among the various manufacturers, formulators, fabricators and users in a manner similar to that provided by existing stainless steel number systems. The task group feels that adoption of the numbering system should prove invaluable in predicting resistivities of equipment and materials of construction in specific environments through knowledge of the actual types, compositions, or modifications of the plastics employed in their fabrication. The main benefit the task group believes, lies in the knowledge that the fabricators and formulators must adhere to certain specifications and standards in order to meet the requirements for a particular Type Number Plastic. This is aimed at up-grading the quality of work done with plastic materials of construction.

Example Is Given

An example of the numbering system is as follows: Suppose Type Numbers 700 through 749 were assigned to Polyester Resins. The polyester resins are special unsaturated alkyd resins copolymerized with certain monomers such as styrene or vinyl toluene through the aid of organic peroxide catalysts, such as benzoyl peroxide, and promoters like cobalt naphthesote.

Initial acid combination of a particular polyester resin would be designated by such numbers as:

700.0 Phthalic Anhydrite and Maleic Anhydride

701.0 Phthalic Anhydride and Fumaric Acid

702.0 Phthalic Anhydride, Maleic Anhydride, and Fumaric Acid

703.0 Adipic Acid, and Maleic Anhydride

704.0 Adipic Acid, and Fumaric Acid

The glycols employed with the above acid combinations to form the unsaturated long chain unsaturated alkyd resins would be numbered:

0.1 Ethylene Glycol
0.2 Propylene Glycol
0.3 1,2-Butylene Glycol
0.4 1,3-Butylene Glycol
0.5 2,3-Butylene Glycol

The Peroxide catalysts would be listed:

0.001 Benzoyl Peroxide
0.002 Methyl Ethyl Ketone Peroxide
0.003 Lauroyl Peroxide

The use of an accelerator would be shown by:

0.0001 Cobalt Naphthenate

Various filler media would be tabulated as:

0.01 Carbon
0.02 Diatomaceous Earth
0.03 Mineral (Asbestos, Mica, Silica, etc.)
0.04 Inorganic Compounds, TiO_2, $CaCO_3$, etc. (to be identified)

Prefix Letters Used

The unsaturated monomeric compounds, cross-linked with the unsaturated esters, would be identified by the use of prefix letters of the alphabet as follows:

A—Styrene
B—Vinyl Toluene
C—Triallyl Cyanurate
D—Diallyl Phthalate
E—Alpha Methyl Styrene
F—Divinyl Benzene

The plastic assigned the number A-702.2121 would be an unsaturated polyester prepared by condensation of maleic anhydride, fumaric acid and phthalic anhydride (702) and propylene glycol (0.2) which has been cross linked with styrene (A), filled with carbon (0.01), through the use of methyl ethyl peroxide (.002) and cobalt naphthenate accelerator (0.0001). It would have physical properties falling within the ranges as assigned to Type Number A-702.2121. These physical properties are given in charts being prepared by the committee.

Properties being included on the chart for a given type number and generic classification are: Specific gravity, tensile strength, elongation, modulus of elasticity in tension, compression strength, flexural strength, impact strength (Izod test), hardness Rockwell, thermal conductivity, specific heat, thermal expansion, resistance to heat, and heat distortion temperature.

ADDITIONAL TECHNICAL COMMITTEE MEETINGS: (First) W. F. Oxford, Jr., Sun Oil Co., Beaumont presiding at meeting of T-1 on Corrosion of Oil and Gas Well Equipment; (Second) W. C. Koger, Cities Service Oil Co. Bartlesville, Okla. presenting a report on oil string casing corrosion at T-1 meeting; (Third) Unidentified acting secretary and J. C. Coffin, Dow Chemical Co., Midland, Mich., chairman, presiding at organizational meeting of T-6D on Industrial Maintenance Coating; (Fourth) W. L. Scull, Colorado Interstate Gas Co., Colorado Springs, Col., acting secretary and T. J. Maitland, American Telephone and Telegraph Co., New York, chairman at a meeting of T-2B on Anodes for Impressed Currents.

Task Groups Proposed by Petroleum Coatings Unit

Unit Committee T-6E on Protective Coatings in Petroleum Production has approved an outline of a plan of action to develop recommendations and suggested practices for the guidance of producers, contractors, etc., in selection and application of protective coatings. The outline provides for task groups as follows:

1. Tanks, 2. Pipe, 3. Heaters (Treaters, Separators), 4. Miscellaneous Oilfield Equipment, and 5. Low Pressure Gas Plants.

Under each task group the following points will be considered: a) Exposure (External—a. rural, b. industrial, c. marine, Internal—type of service). b) Surface preparation. c) Material selection. d) Inspection procedure and e) Experience.

At the committee meeting in San Antonio during the South Central Region meeting a questionnaire to develop information on current practices was discussed.

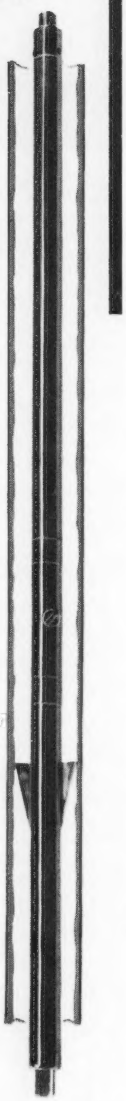
The committee expects to hear progress reports from each task group at the meeting in St. Louis next March.

Pipe Line Plastic Film Questionnaire Prepared

The History and Results Task Group of Unit Committee T-2K has prepared a questionnaire on prefabricated plastic films for pipe line coating. The committee hopes to get the questionnaire circulated soon.

Meetings of Unit T-2K were held at Philadelphia and San Antonio during the Northeast and South Central Region meetings. Plans are being made to prepare recommended specifications for prefabricated plastic film that can be used in the T-2 Minimum Requirements for Pipe Line Protection Report. The committee continues to gather performance data on plastic films.

THE BARNES
LIQUID
DUMP
BAILER



Saves
TIME,
MATERIALS
and
MONEY

Shut-in periods are slashed when this liquid corrosion inhibitor dump bailer is used in producing oil or gas condensate wells. Average time per 8,000 to 9,000 ft. is only one hour. This saving in time *cuts labor costs to a new low* for corrosion inhibitor treatment. Easily lowered from conventional wire line.

SAVES MATERIALS

By using *concentrated* liquid inhibitor, it forms a *superior* protective film as it moves up the string. Five quarts of inhibitor are *all* that are required to protect the average well for a month or longer.

SAVES MONEY

Your average cost for corrosion treatment may be reduced to as low as four mills per barrel of oil produced by using this Liquid Dump Bailer. Call Galloway Engineering Co., distributor of this revolutionary new system, for complete details.

GALLOWAY

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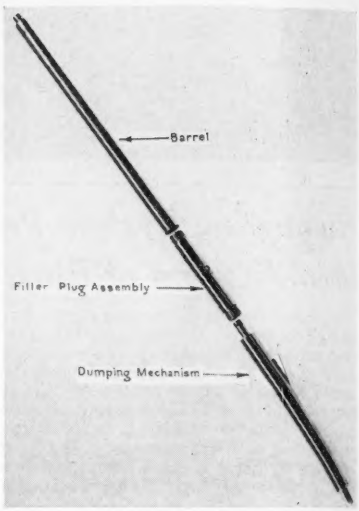
Oil Well Inhibitors Applied at Any Level By Improved Liquid Type Dump Bailer Device

A preliminary report on the use of a liquid type dump bailer for the treatment of oil and gas wells was presented at the meeting of T-1 on Corrosion of Oil and Gas Well Equipment during the South Central Region meeting in San Antonio in October.

Treatment of gas-condensate and flowing oil wells with organic corrosion inhibitors has always been difficult. Operators have been in doubt as to whether the inhibitor was getting to the bottom of the tubing string because well conditions often complicated the efficient use of lubricators or pumps injecting inhibitors.

Inhibitors injected by pump or lubricator into the tubing at the wellhead often gave protection only to the upper string, while middle and lower sections continued to corrode. This effect was substantiated by tubing caliper surveys.

Because a "down-the-hole" mechanical means of depositing a volume of an inhibitor at the bottom of the well was needed a wire-line liquid-type dump bailer was designed to allow the operator to protect all or any portion of the tubing string. The bailer discussed in the report consists of three major parts: 1) A barrel to contain the liquid inhibitor; 2) The filler plug assembly and 3) The dumping mechanism. Overall length of the dump bailer is eleven feet. The 1¼-inch diameter barrel is nine feet long. Volume of the barrel is 2.3 quarts.



Bailer Trips Coming Up

Models of the bailer now being used empty themselves upon being withdrawn after a collar trip breaks an O-ring seal when it strikes the first collar coming up. This permits dumping inhibitor at any desired depth. Earlier models tripped when the bailer struck the bottom of the perforated nipple or a bomb stop.

The bailer is lowered into the well on a wire line. A portable lubricator, sufficient in length to handle the bailer used and equipped with a wire line blowout preventer and stuffing box, is used for injecting and retrieving the bailer.

Because the bailer's volume is limited a concentrated inhibitor is used. Increased viscosity of the concentrated inhibitor posed a problem to operators and a hand pump had to be employed to pump the concentrated liquid into the barrel of the bailer. It was found that at concentrations of about 80 percent most liquid inhibitors were too viscous to be pumped effectively, so concentration ranges have been established from 50 to 80 percent depending upon the viscosity of the inhibitor used.

Principal Advantages Given

The most important advantage of using the dump bailer is it permits exposure of all of the internal surface of the tubing to inhibitor. The degree of protection offered depends on treatment frequency and amount. Two other advantages are: 1) Shut-in periods, during or after treatment, are limited to about one hour for a run of 8000 to 9000 feet, and 2) Field personnel are relieved of treatment duties because contract labor usually is employed to run the dump bailer.

The major disadvantage is the limited volume of inhibitor per treatment imposed by the barrel volume. In the treatment of an entire field on a regular schedule of two treatments per month, the treatment ratio (barrels per pound of active inhibitor) for each well varies according to the individual well's production. The remedy appears to be to increase treatment frequency on wells with higher production rates. Economics of treatment would be the only obstacle preventing operators from increasing the treatment frequency.

Further work must be done to get answers to such questions as how often a well must be treated with a dump bailer to obtain maximum protection; what concentration of the inhibitor is best and what is the persistence of the adsorbed film. Such answers ultimately will yield an average treatment ratio and frequency which can be applied to every well treated with the dump bailer.

More Rectifier Standards Considered by Unit T-2B

Unit Committee T-2B on Anodes for Impressed Current has assigned a task group to investigate the possibility of preparing suggested standard specifications for cathodic protection rectifiers using silicon, copper oxide, germanium and other materials. The task group had previously cooperated with the NEMA in preparation of rectifier standards.

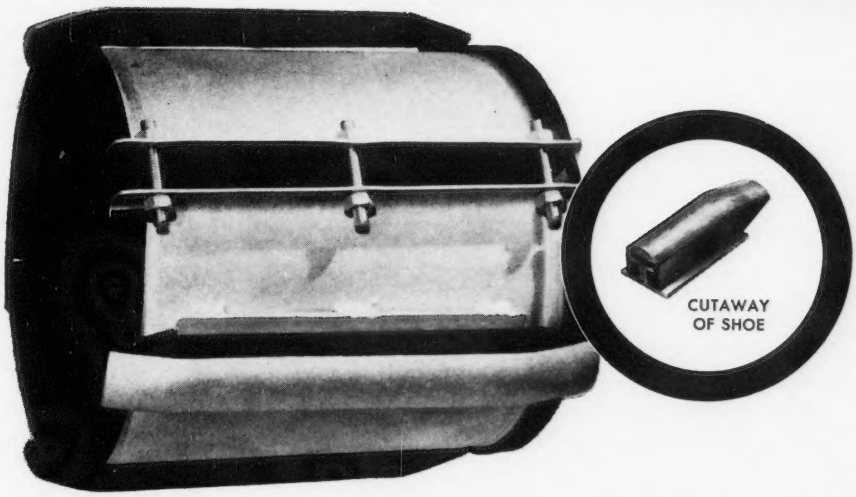
A task group on high silicon cast iron anodes reported on revisions made to a previous interim report at the committees' meeting in San Antonio. It is anticipated the interim report will be submitted for publication in the near future.

Another task group of T-2B reported it had received information on ground bed design data from 30 companies. The group will digest the information for future presentation to the unit.

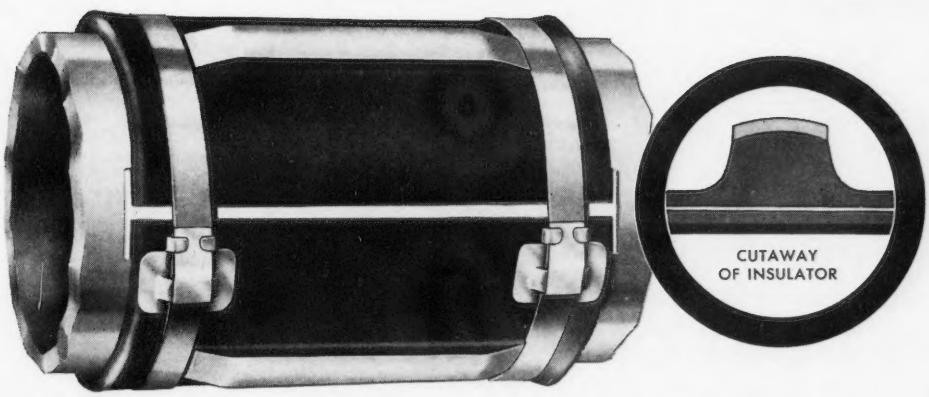
●

The distinctive NACE membership emblem is available to all NACE members at $10.

Model 55 Maloney Insulators for LARGE JOBS



Model 56 Maloney Insulators for Small Jobs



Maloney Insulators for *Every Job!*

Maloney Crossing Insulators for pipeline casing are exceptionally rugged, easy-to-install... and adaptable to a wide range of pipe sizes and differentials.

Because they are bonded metal-to-neoprene-to-metal, Maloney Insulators provide good shock-absorption, plus flexibility to compensate for pipe shifting.

Streamlined "sled-type" steel runners make for easy entry into the casing, and prevent hanging-up on casing welds as pipe is being run.

Model 55 Maloney Crossing Insulators, in all sizes through 36", are fitted with an extra-wide steel band for positive grip. Model 56, for pipe sizes through 12" with 2" nominal pipe size differential, are fastened to the carrier pipe with stainless steel bands. Both types offer greater dependability—greater protection against corrosion with high dielectric strength neoprene, and against physical damage with steel runners—than any other insulator on the market. Maloney Crossing Insulators are in use on most of the country's major pipelines.

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SINCE 1932 — PRECISION IN RUBBER — METAL — PLASTICS

Northeast Region Coordinating Committee Has Organization Meeting at Philadelphia Oct. 15

First meeting of NACE Technical Unit Committee T-7A Northeast Region Coordinating Committee was held October 15 in conjunction with the Northeast Region Fall Conference in Philadelphia. Representatives of several existing coordinating committees were present at the meeting and all expressed enthuiastic approval of the aims of the T-7 committees.

C. A. Erickson, Peoples Natural Gas Company, Pittsburgh, chairman of T-7A explained the method to be used to publish and maintain a list of individuals in specific areas to be contacted in regard to joint tests, etc. The list is scheduled to be published in the Technical Committee Directory that appears in CORROSION on alternate months. Chairmen of all area committees who will be listed will have a list of individuals with companies in the area who should be contacted in regard to coordination activities.

By-Laws Suggested

Plans for committee work includes drafting suggested by-laws for coordinating committees and suggested standard notification forms. T-7A also voted to recommend to the Group Committee T-7 that the Report of the Correlating Committee on Cathodic Protection published in 1951 be revised and rearranged to cover T-7 recommended coordination procedures and that the revision be published.

C. A. Erickson, Peoples Natural Gas Company, Pittsburgh, Pennsylvania and Andrew Kellogg, Niagara Mohawk Corporation, Syracuse, New York were elected permanent chairman and vice chairman respectively of the committee.

South Central Group Meets

A second meeting of the T-7 committee was held in San Antonio, Texas on October 24. This meeting was held to organize a South Central Region Area Committee. The committee will be called Unit Committee T-7 South Central Region Corrosion Coordinating Committee. O. W. Wade, Transcontinental Gas Pipe Line Corporation was elected chairman and C. L. Woody, United Gas Corporation was elected vice chairman.

This committee will use the same method as T-7A for publishing a list of individuals to contact in connection with coordination work. It also agreed the Report of the Correlating Committee on Cathodic Protection should be revised and published.

C. L. Roach of the Bell Telephone Company of Canada in Montreal, Quebec has agreed to be chairman of the T-7 unit committee to be organized in Canada. This committee will be known as Unit Committee T-7F Canadian Region Corrosion Coordinating Committee.

Reports on organization of T-7 unit committees in the North Central and Southeast Regions will be published later.

SAVE 1 OUT OF 3 ANODES IN HOT SPOT PROTECTION

It's true! A new procedure using new-size "Galvomag" anodes enables you to save one out of three on "hot spot" protection for pipe lines.

The savings come because you use one-third fewer magnesium anodes than were formerly required. Also you save on freight, handling, and installation time and costs.

Want to know more about this new method? Write for additional facts. CSI engineers will be glad to help you figure applications to your own pipe line and well casing problems—and calculate your savings. No obligation.

CSI also offers expert consultation services and a complete line of brand-name cathodic protection materials, including Dow Galvomag and other Dow magnesium anodes. CSI has the trained personnel, power augers and ditching machines to handle your installation requirements.

For competitive cost estimates or quotations, call or write today.

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Asphalt Coatings Unit Discusses Specifications

Austin S. Joy, Brumley-Donaldson Company, Huntington Park, California has been elected chairman of NACE Technical Unit Committee T-2H on Asphalt Type Protective Coatings for Underground Pipe Lines. He was elected to fill the vacancy left by the resignation of R. J. Schmidt, California Research Corporation, Richmond, California. Mr. Schmidt resigned because of increased responsibilities in his company's work. He will remain on the committee as a member. P. E. Reynolds, Pacific Gas & Electric Company, San Francisco, California remains as vice chairman of the committee.

Joy

A meeting of T-2H was held in San Antonio during the recent South Central Region meeting. The committee discussed revisions to the proposed specifications for asphalt wrapped and mastic type pipe coatings. In addition a new task group was formed to prepare proposed specifications for internal pipe coatings.

A second meeting of the committee was held in Long Beach, California during the Western Region Conference. Information on that meeting will be available later.

TYGORUST—

bonds vinyls and other finishes securely after minimum surface preparation

Before the development of Tygorust it was frequently necessary to sandblast, scrape or chip rusted surfaces before priming could be started. Now, with Tygorust, it is only necessary to wire-brush loose rust and scale—and prime. The surface need not even be dry. Tygorust works equally well on damp or dry surfaces, penetrating through the rust to lock securely to the steel itself. It bonds tightly to clean or rusted steel and eliminates underfilm rust-creep—it goes over firmly adhering old paint (excepting bituminous coatings). It successfully primes damp or dry concrete—in fact with its unusual properties it makes an ideal general purpose primer for plant-wide maintenance. It is easy to apply by brush or spray and provides economical coverage.

Tygorust is the perfect priming base for vinyl-based paints, making them as easy to use as ordinary paints. But Tygorust works equally well with all other types of finish coat too. However, for the ultimate in corrosion resistance topcoat Tygorust with Tygon Protective Paints. Tygon and Tygorust are a time-tested team that provide the maximum in plant-wide corrosion protection.

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TO HELP YOU COMBAT CORROSION...

Write for your free copy of The Tygon Paint Manual. Its 30 pages contain a wealth of helpful facts. Subjects include: Surface preparation; top coating for corrosive service; maintaining painted surfaces; solutions to common spray problems; and other subjects of equal interest.

Plastics and Synthetics Division

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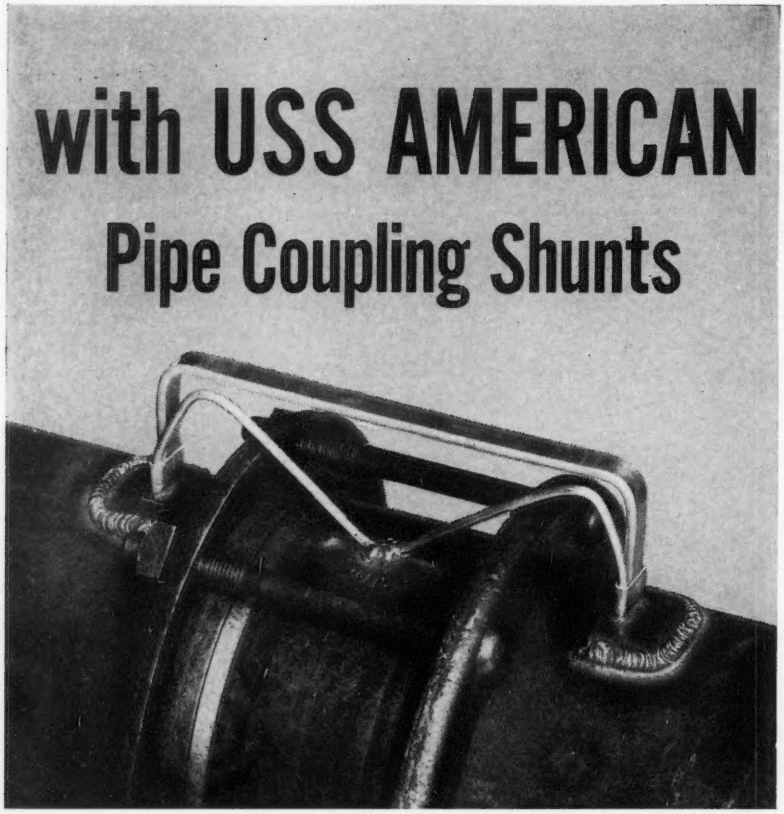
Fight corrosion and save money

with USS AMERICAN Pipe Coupling Shunts



They're prefabricated, and curved to fit the pipe! USS American Pipe Coupling Shunts are designed especially for easy application on mechanical pipe couplings. They save the time and labor of fabricating home-made shunts, are easier to install, and do a better job of preventing electrolytic corrosion.

Terminals and secondary conductors are steel. Main conductor is heavy copper bar. Conductors are welded permanently to the pipe and coupling to keep entire assembly at same potential.

Write for information about cathodic protection devices manufactured by American Steel & Wire These include pipe coupling shunts; anode connectors; suspended anode connectors for piers, dry docks, ships; and coupon connectors for connecting leads to pipe.

AMERICAN STEEL & WIRE
DIVISION, UNITED STATES STEEL
GENERAL OFFICES: CLEVELAND, OHIO
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO, PACIFIC COAST DISTRIBUTORS
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA., SOUTHERN DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS

USS AMERICAN PIPE COUPLING SHUNTS

UNITED STATES STEEL

Ship Hull Cathodic Protection Report Draft Is Presented

A tentative draft of an initial report on Cathodic Protection of Hulls was presented by Task Group T-3G-1 at the meeting of T-3G on Cathodic Protection held in San Antonio.

The report is divided into five sections as follows: 1—Application of cathodic protection to ship hulls. 2—Measurements of protection. 3—Sources of protective current. 4—Use and influence of coating systems on cathodic protection. 5—Factors which influence protective current requirements.

Section 1. The report says cathodic protection can be applied successfully to prevent corrosion of exterior underwater areas of all steel hulled vessels and defines the term hull to mean the exterior surface of any object used in marine service for the primary purpose of maintaining or regulating buoyancy.

Section 2. Methods are given for measuring protective effect by measurement of the hull potential to a reference electrode, periodic comparison of the hull plate dimensions and by examination of corrosion products on the hull.

Section 3. Compares cathodic protection systems giving advantages and disadvantages for the sacrificial galvanic anode system and the energized inert anode system. Characteristics of inert anodes are given. Properties of galvanic anodes are given and the galvanic anode current (approximate output in sea water) of some galvanic anodes are given.

Section 4. Presents a discussion of the use and influence of coating systems on cathodic protection. In general the ideal protective state to maintain on a coated hull is to assure corrosion control at any exposed area on the hull without applying excessive current which will accelerate coating deterioration.

Coatings used in combination with cathodic protection should not be affected by cathodically produced alkali, retain adhesion and should have a high electrical resistance.

Section 5. In general, says that factors which reduce corrosion will reduce the protective current requirements. Protective current requirements for mild steel hulls in sea water range from 0.1 ma/sq. ft. for well-coated surfaces to 10 ma/sq. ft. for bare moving hulls. Factors which reduce protective current requirements and factors which increase protective current requirements are discussed.

Netherlands Consulting Engineers Issue Magazine

"The Way Ahead" is the title of an English language quarterly magazine published by Stichting Bouw, P. O. Box 299, Rotterdam, The Netherlands as a review of the activities of consulting engineering in Holland. The publication, first issued in 1947, and intended to create goodwill for the Netherlands and further export trade, is available by subscription at $3 a year.

Volume 5, No. 4 contains articles on aerial survey techniques, water management and land use, storehouses for potatoes, the use of bitumen in hydraulic works, application of plant layout techniques.

BUSY HOURS were spent at the registration desk serving the more than 900 who attended the San Antonio meeting of South Central Region in October.

NACE NEWS

San Antonio Meeting Attendance Is Over 900

Full Technical, Social Program Presented by South Central Region

Following the pattern of recent years the October South Central Region meeting in San Antonio was crammed full of technical sessions and topped off with enjoyable social events. Registration was given unofficially as 913, including 143 ladies.

Consistently well attended technical committee meetings emphasized the growing importance of this activity of the association at the regional level. Some sessions were held with standing room only. Technical symposia were well received and well attended. While attendance was predominantly from Southwestern states there was a sprinkling of registrants from other parts of the nation as far west as California; east to New York and Georgia; north to Chicago and south into Mexico.

Social Events Colorful

NACE members in San Antonio Section took full advantage of the historical background and Latin American culture for which their city is famous. The annual Fellowship Hour featured a buffet of Mexican-style food which received universal attention from the some 1000 persons who attended.

At ceremonies on the colorful San Antonio river in the Arneson Theater, scrolls making him an honorary Texan and "Alcalde de San Antonio" were given to NACE President W. F. Fair, Jr. A present was given also to Mrs. Fair on behalf of the mayor of San Antonio.

John W. Nee, South Central Region chairman, capped off the ceremonies by presenting a ten gallon hat to Dr. Fair with the best wishes of the region. Dr. Fair was so surprised by these events he was almost at loss for words, and the hat became a prominent part of his dress during the remainder of the session.

W. F. FAIR, JR., Koppers Co., Pittsburgh sports the badge of Texas Citizenship, a ten-gallon hat, at ceremonies preceding the 1956 annual banquet of South Central Region at San Antonio. Dr. Fair, president of NACE, also was made "Alcalde de San Antonio" by official proclamation of the mayor.

Banquet Is Enjoyed

Following presentation of a program consisting of typical Mexican songs and dances by a troupe of gaily dressed Latin American performers, the banquet was held in La Villita, the area reconstructed to resemble the first Spanish settlement at San Antonio.

Dancing was enjoyed by hundreds.

Mail Ballot to Be Used For Regional Election

The annual meeting of South Central Region, presided over by John W. Nee, Briner Paint Co., Corpus Christi, was held as the last event of the week at the region's October meeting in San Antonio.

Mr. Nee reported that the 1957 regional meeting had been scheduled for Oklahoma City, October 1-4; and in 1958 at New Orleans, Oct. 20-24.

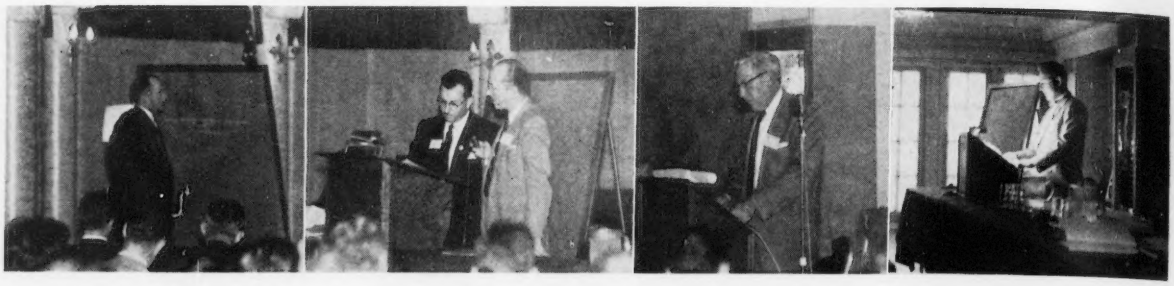
Election of regional officers will be by letter ballot, Mr. Nee reported, it having been concluded that the number present at the annual meeting was not sufficient to constitute a quorum of the region. Candidates named by the nominating committee are Jack P. Barrett for chairman; J. C. Spalding, Jr. for vice-chairman; J. A. Caldwell for secretary-treasurer and William F. Levert for assistant secretary-treasurer. Brief biographies of these nominees were published in CORROSION'S August issue on Page 78.

John E. Loeffler, Thornhill-Craver Co., Houston, trustee-at-large was honored with presentation of a past chairman's certificate by the region.

Judson S. Swearingen, director of the Petroleum Technology Division of Southwest Research Institute, San Antonio described plans underway for expansion of the institute.

Corpus Christi Section

John W. Nee, Briner Paint Manufacturing Co. was the scheduled speaker on "Polyamide Resins—A New Surface Coating," before a meeting of Corpus Christi Section October 16.



SOME OF SPEAKERS AT SYMPOSIA during the October meeting of South Central Region were, left to right, (First) Pearce R. Butterfield, Transcontinental Gas Pipe Line Corp., Houston delivers his paper "Cathodic Protection of Compressor Stations"; (Second), left, unidentified discussor and right, E. J. Simmons, Sun Oil Co., Dallas, who gave a paper titled "Factors to Be Considered in Evaluating Corrosion Inhibitors"; (Third) Harry Blackwell, Texas Electric Service Co., Fort Worth discusses "Corrosion in Power Plants," during the symposium on Corrosion in the Utilities Industry; (Fourth) C. F. Schreiber talks about "External Ship Hull Protection" during the Transportation Industry symposium.

San Antonio Exhibition Gets Favorable Comments

Joe Rench, Napko Corporation, Regional Exhibit Chairman for the South Central Regional meeting at San Antonio in October said all comments which he received from both exhibitors and visitors at the meeting were favorable to regional exhibits. Mr. Rench also said that as an exhibitor that Napko was more satisfied with the results at the South Central Regional meeting than any other in which it has participated. He also expressed his appreciation for cooperation received from the regional officers and members of his committee.

Firms who exhibited and were not listed in the October issue of CORROSION are: Cosasco Div. Perfect Circle Corporation, La Canada, Cal.; Lester Equipment Manufacturing Company, Los Angeles, Cal.; Standard Magnesium Corporation, Tulsa, Okla.

TWO SCENES at the Ladies Hospitality Headquarters. A daily morning get-together was enjoyed, plus a full program of tours, style shows, luncheons and other social events.

Western Region Sessions Held Nov. 15-16 On Pipelines, Process Equipment, Plastics

Sessions on pipelines and process equipment protection were held concurrently November 15 at the Lafayette Hotel, Long Beach, Cal. as features of the fall 1956 meeting of Western Region NACE. On Friday, November 16 sessions were held on new developments in plastics and during the afternoon nine reports on work of NACE technical committees were given.

The two-day meeting followed the University of California at Los Angeles Short Course on "Practical Considerations of Underground Corrosion for Non-Technical Personnel."

Preston W. Hill, Signal Oil & Gas Co., Long Beach, Western Region chairman, opened the conference at 9:30 am on the 15th. W. F. Fair, Jr., Koppers Co., Pittsburg, NACE president spoke at 10 am and R. E. Hall, Union Oil Co., Brea, Cal. previewed the meeting at 11 am. Buffet luncheon was served at 11:30 am and at 5:30 pm a social hour and banquet were held.

The scheduled technical meeting was:

November 15

New Developments in Pipeline Protection, L. E. Magoffin, California Water & Telephone Co., program co-chairman.

Engineered Light Weight Steel Pipelines, C. E. Lamar, Southern Pipe & Casing Co.

Pipeline Construction Practices for Economical Cathodic Protection, C. E. Hedborg, Union Oil Co. of Cal.

New Ideas on Graphite Anodes, W. W. Palmquist, National Carbon Co.

High Silicon Cast Iron Anodes, M. E. Parker, Cormit Engineering Co.

Selenium vs Silicon in Cathodic Protection Power Supplies, Don P. Wilson, Lester Equipment Manufacturing Co.

New Developments in Process Equipment Protection, C. M. Schillmoller, International Nickel Co., Inc., program co-chairman.

(Continued on Page 122)

Articles Scheduled For January Issue

The following technical articles are scheduled for publication in January, 1957 CORROSION:

Symposium on Corrosion High Purity Water

Symposium on Corrosion by High Purity Water—Introduction, John F. Eckel.

Importance of High Purity Water Data to Industrial Applications, W. Z. Friend.

Corrosion Engineering Problems in High Purity Water, D. J. DePaul.

Corrosion Resistance of Materials in High Purity Water, A. H. Roebuck.

Other Papers and Reports

Analysis of Corrosion Conditions Using Cable Sheath Current Measurements, J. M. Fouts and C. W. Bergerson.

A Study of Galvanic Corrosion, James T. Waber.

Electrical Resistance Corrosion Measurements Employing Alternating Current, W. L. Denman.

Analysis of Corrosion Pitting by Extreme-Value Statistics—Application to Oil Well Tubing Caliper Surveys, G. G. Ethredge.

Chemical Surface Preparation of Metal Prior to Painting, H. E. Patterson.

An Engineering Approach to the Estimating of Maintenance Painting, R. F. Williams and J. H. Cogshall.

Stray Current Electrolysis—A Report of NACE Committee T-4 B on Corrosion of Cable Sheaths.

THESE TESTS PROVE CORBAN PREVENTS CORROSION BEST

Many methods of stopping corrosion have been tried. Corban®, developed by Dowell, is proving to be both effective and economical. The tests at right show the actual results that have been realized with Corban.

Test Corban on your own corrosive wells. You'll find that proper application of Corban will result in money-saving reductions in equipment failures – time and again!

Field experience has proved that Corban extends the life of tubing, casing, fittings, and valves. It also saves time and production by helping avoid workovers necessitated by corrosion-damaged equipment.

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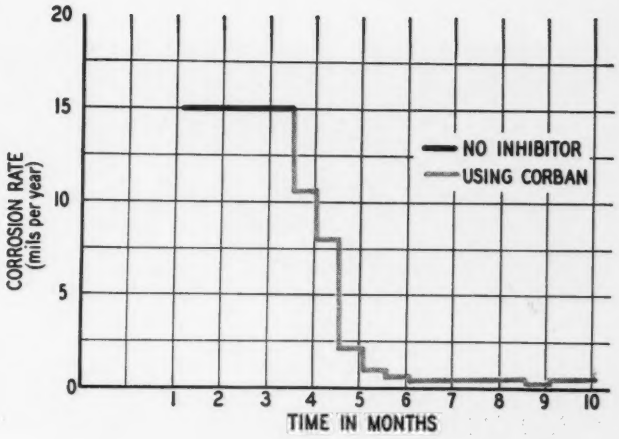
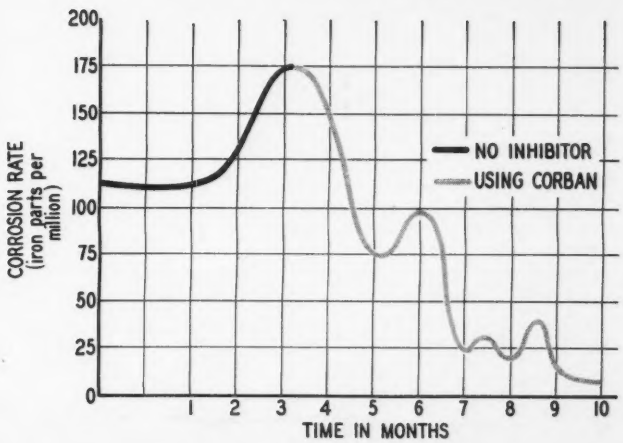
Let us recommend a program of well treatment designed especially for your wells. Call any of the 165 Dowell offices in the United States and Canada. In Venezuela, contact United Oilwell Service. Or write Dowell Incorporated, Tulsa 1, Oklahoma.



1 STANDARD TEST uses metal strips inserted in wellhead or tubing. Surface penetration or weight loss indicates degree of corrosion.



2 FLUID ANALYSIS is quick test of corrosion in gas condensate wells. Chart shows parts per million of dissolved iron in water sample.

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Whimsical View of Corrosion Engineer Feature at Houston

Houston Section members—who stick to the business at hand, learning ways to combat corrosion—at almost every section meeting, will turn their energies and talents to having fun at the December 11 meeting.

The meeting, to which wives are particularly invited, will feature a theatrical production: "Corrosion Engineer, This Is Your Life," a two-act, four-scene play. Director of the production is Joe Rench, Napko Corp., Houston. Wives will be able to see in this intense drama the never-ending battle their husbands put up in their fight against corrosion.

The first act will show the corrosion engineer on the job. Scene one will depict him as he sees himself. Scene two will show the corrosion engineer as others see him.

How He Looks at Meetings

The second act will show the corrosion engineer as he meets with other heroic battlers of corrosion assembled in halls of scientific learning at technical conventions. Scene one will show the corrosion engineer as he thinks he looks at these conclaves and scene two will be a startling portrayal of this same corrosion engineer as a discerning bystander sees him in convention.

Director Rench, in addition to being director is also producer, writer and scene shifter for the play. He is keeping his stellar cast secret. Pearce Butterfield, Transcontinental Gas Pipe Line Corp., Houston is chairman of the section program committee.

Fellowship Hour To Be Held

The meeting will be held at John's restaurant, 9350 S. Main St., Houston. Fellowship hour begins at 6 pm, the dinner at 7 pm and the program at 8 pm. Wives are urged to attend so they can become acquainted with the difficulties their husbands face on their jobs.

At the January meeting, the section will get back to serious business. Subject for the meeting will be "Corrosion by Recirculating Cooling Water." C. P. Dillon, Carbide and Carbon Chemicals Co., Union Carbide and Carbon Corp., Texas City, Tex. will act as chairman and moderator of a panel. Other members will be A. P. Pettyjohn, who will discuss the chemistry of corrosion and water treatment to prevent corrosion; and L. M. Rodgers who will talk on testing techniques.

Burns Gets Acheson Medal

R. M. Burns, senior technical adviser to Stanford University Research Institute has been awarded the Acheson Medal of The Electrochemical Society for 1956. The medal and a prize of $1000 were presented to Dr. Burns during the Cleveland meeting of the society October 2.

MEXICAN-STYLE BUFFET supper at the Fellowship Hour during the South Central Region's meeting in San Antonio was extremely popular, as the top photograph shows. Others among the approximately 1000 persons present are shown in the other views.

THE SOLUTION:

In-Place *Coating with Humble Epoxy Internal Pipe Coatings*

Humble's epoxy internal pipe coatings can be applied *in-place* in a single application in new or used pipe. They effectively stop corrosion in pipelines that are exposed to extreme internal corrosive conditions, and greatly extend the life of these lines. Several miles of pipe can be coated internally at one time.

In addition to giving excellent resistance to sour crudes and brine, Humble epoxy internal pipe coatings give a smooth, glossy finish that cuts down paraffin deposition.

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Technical Service
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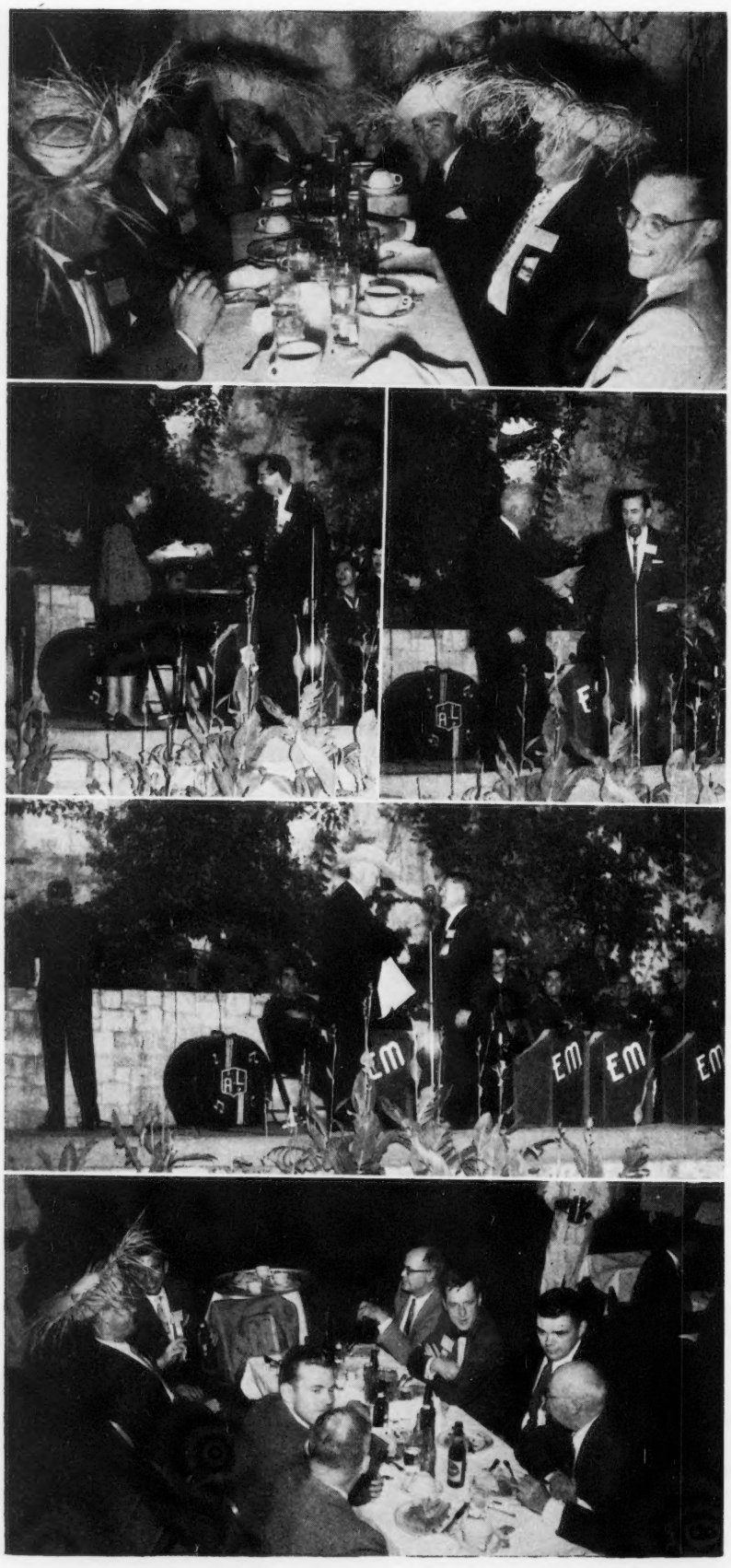


Jan. 31-Feb. 1 Dates Set for Houston Corrosion Course

The 1957 short course on corrosion of Houston Section will be held January 31-February 1 at University of Houston. O. W. Wade, Transcontinental Gas Pipe Line Co., Houston director of the school said the course would be organized to give practical working information on control of underground corrosion.

Some changes in the schedule were made in an effort to increase the instruction time of the course. An additional 5 hours of time was added through changes made, which include earlier starting and a two-hour night session. Persons attending will be encouraged to eat breakfast at the university cafeteria to permit starting instruction at 8 am daily.

A tentative time schedule was given as follows:

January 31—8 am to 12 noon; 1 pm to 5:50 pm; 7 to 9 pm. (Supper is available at the University of Houston Cafeteria).

February 1—8 am to 12 noon; 1 to 5 pm.

Registration fee of $10 will cover the cost of a printed version of the course content for each registrant. Advance registrations accompanied by the $10 fee will be accepted by O. W. Wade, Transcontinental Gas Pipe Line Corp., Box 296, Houston 5, Texas. Advance notices will be mailed to all NACE members in South Central Region and plans have been made to send notices by mail to other selected names in other NACE regions.

Indexing Changes to Be Made in 1957 Corrosion

Beginning with the first issue of 1957 CORROSION's accumulative pagination in the Technical Section will be extended to include reports of NACE Technical Committees. This will permit including all of the reports in the annual alphabetical indexes.

Practice during 1956 has been to include in Technical Section pagination only those reports to which an NACE publication number is assigned. Reports designated as "progress, status," or as "contributions" have not been assigned publication numbers.

It is contemplated also that the index to Volume 13, scheduled for publication in December, 1957 will omit the tabular topical index, as was the case in December, 1956 with respect to the index to Volume 12.

•

A chronological list of all articles published in CORROSION's Technical Section 1945-54 may be found in the 10-Year Index to CORROSION.

FRANTIC HATS on these merry-makers (top) at the South Central Region's annual banquet brought many a laugh. In the second photograph at left Mrs. W. F. Fair, Jr. is shown receiving a gift from the mayor of San Antonio; at the right, W. F. Fair, Jr., NACE president, receives the scroll signed by the governor of Texas making him an honorary Texan. In the third panel from the top Dr. Fair thanks John W. Nee, Briner Paint Co., Corpus Christi, South Central Region chairman for his ten gallon hat. The bottom view shows another group of merry-makers.

Pittsburg Hears Brown on Fundamentals of Corrosion

Fundamental concepts on the mechanism of metal corrosion were discussed at a meeting of Pittsburgh Section November 1. R. H. Brown. Chief, Chemical Metallurgy Division, Alcoa Research Laboratories, Aluminum Company of America, New Kensington, Pa. was the technical speaker. His topic was "Some Basic Factors Involved in Corrosion Investigation."

Brown

About 60 persons were present for the technical program and the business meeting. There were 51 members and guests at dinner at Pittsburgh's new Gateway Plaza, overlooking the rejuvenated "Golden Triangle."

Mr. Brown cited an interesting fact that intensity of corrosion attack is more dependent on the area unattacked than on the area attacked, the two areas functioning as irreversible electrodes. In a new approach to the problem of irreversible electrodes, Mr. Brown said, it has been shown that the reversible electrode is a highly specialized case of the irreversible electrode.

Main topic at the business meeting was a request by Northeast Region that Pittsburgh Section sponsor the region's 1957 fall conference. It was agreed unanimously after discussion that Pittsburgh Section would accept. Chairman L. G. Royston, Royston Laboratories called a meeting for November 6 to work out details.

Hoover Is Named Trustee By Kansas City Section

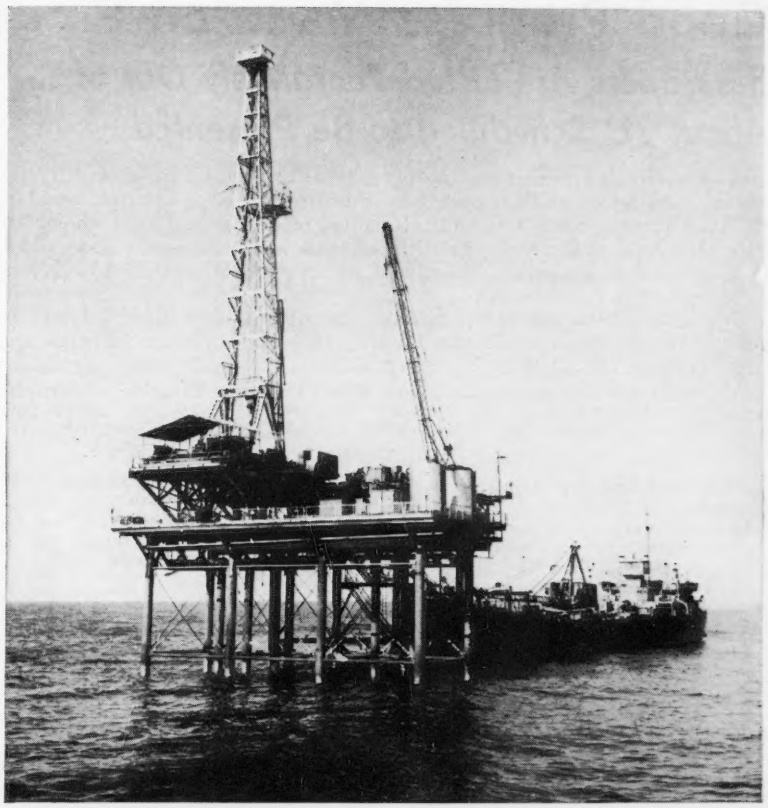
The first fall meeting of the Kansas City Section was held October 1 at the Wishbone Restaurant in Kansas City, Missouri. During the business portion of the meeting William Hoover of the Koppers Company was appointed section trustee and Chairman J. C. Berringer appointed a nominating committee consisting of A. L. Kimmel, Fred Few, and Jack Grady to report prior to the next regularly scheduled meeting.

Following the section business, a film entitled "Zinc Controlled Corrosion" prepared by the American Zinc Institute was shown, followed by a short talk presented by G. M. Goode of the Rogers Galvanizing Company of Kansas City.

Northeast Region's Spring Meeting Set May 20-22

The spring 1957 meeting of the Northeast Region has been scheduled for May 20-22 at Syracuse, N. Y. The 1958 spring meeting of the region is scheduled tentatively for Boston, probably also in May.

Some consideration is being given to the desirability of the region holding one meeting yearly, in the fall of the year. Decisions on this point will not affect the Syracuse meeting, however.

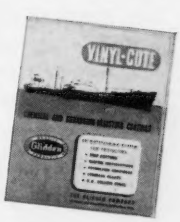


Glidden VINYL-COTE protects offshore platforms!

Salt water corrosion is a primary problem on offshore drilling and producing platforms like this one, located 10 miles off the Louisiana Gulf Coast. Yet, engineers report that this rig is completely free from corrosion or fouling after 16 months' service. Similar results have been reported on other installations after 3½ years' service.

This corrosion problem and others are solved by VINYL-COTE, the superior vinyl resin that combines maximum corrosion resistance with film toughness, adhesion and flexibility. Glidden VINYL-COTE sprays easily, dries quickly and cures in either air or water. It can be used on metal, concrete, masonry or wood, offers five to ten times the service life of conventional coatings.

VINYL-COTE is only one of the many protective coating systems that Glidden supplies for the protection of industrial installations. Glidden corrosion engineers will survey your corrosion problems and offer specific recommendations for their solution. Write for complete information or contact the nearest Glidden Sales Office.



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Good Progress Made on Program for St. Louis

52 Papers Are Listed Tentatively Out of About 70 Scheduled to Be Presented

Out of some 69 contemplated papers, scheduled to be given during the technical program at St. Louis, 52 committments have been reported by R. T. Effinger, Shell Oil Co., Houston, technical program chairman. The 13th Annual Conference and Exhibition of the National Association of Corrosion Engineers is scheduled to be given March 11-15, 1957 at St. Louis.

Ten of the 13 scheduled symposia are substantially filled. Also to be held are two round table discussions, three educational lectures and small group discussions for pipeliners.

The tentative program compiled and published October 11 shows the following: (Titles sometimes are indicative only)

Chemical Industry Symposium

Chairman: B. J. Philibert, Mathieson Chemical Corp., Baltimore; co-chairman: Russell E. Gackenbach, American Cyanamid Co., Bound Brook, N. J.

Heat Transfer Through Coated Metal Surfaces, R. P. Lee, National Lead Co., Titanium Div.

Chemical Resistant Masonry Construction, Robert R. Pierce, Pennsylvania Salt Manufacturing Co.

Corrosion in Amine Gas Treating Solutions, Frances S. Land and John F. Mason, Jr., International Nickel Co.

Use of Aluminum Alloys With Short Chain Aliphatic Gases, A. B. McKee and W. W. Binger, Aluminum Company of America.

Case Histories of Stress Corrosion Cracking of Austenitic Stainless Steels Associated with Chlorides, H. R. Copson and C. F. Cheng, International Nickel Co., Inc.

Two papers from authors at U. S. Steel Corp.

Stress Corrosion Cracking in Austenitic Stainless Steels, an author from Koninklijke/Shell Laboratory, Amsterdam.

Oil and Gas Production Symposium

Chairman: W. F. Oxford, Jr., Sun Oil Co., Beaumont; co-chairman: Jack L. Battle, Humble Oil & Ref., Co., Houston.

Protective Coatings Symposium

Chairman: L. S. VanDelinder, Carbide and Carbon Chemical Co., Union Carbide and Carbon Corp., South Charleston, W. Va., co-chairman: Norman H. Burnett, Huntington Rubber Mills, Portland, Oreg.

Plastisol Coatings, D. R. Meserve and F. L. Scott, Metal and Thermit Corp.

Container Coatings for Industry, L. J. Nowacki, Battelle Memorial Inst.

An Industrial Painting Contractor Sounds Off, L. L. Sline, Sline Industrial Painters.

Refinery Industry Symposium

Chairman: J. F. Mason, Jr., International Nickel Co., Inc., New York; co-chairman: Howard H. Bennett, Socony Mobil Oil Co., Paulsboro, N. J.

(Continued on Page 113)

Ladies' Program Is Given Tentatively

Following is the tentative program arranged for ladies attending the 13th Annual NACE Conference at St. Louis March 11-15. Mrs. Mary Ellen Young, chairman of the Ladies' Program Committee said all activities are included in the registration fee and all transportation will be furnished. The headquarters room in the Sheraton-Jefferson Hotel will be open daily for card playing.

Sunday, March 10

2:30 pm—Welcoming Hour. Tea and coffee will be served at the Ladies Headquarters Room, Sheraton-Jefferson Hotel.

Monday, March 11

9-10 am—Get acquainted and coffee hour.

2-4 pm—Fashions in flowers program: Special instructions in flower arrangement.

Tuesday, March 12

9-10 am—Coffee hour and Meet St. Louis program.

10:30-3 pm—Shopping tour of fashionable Clayton shopping district. Private cars furnished.

Thursday, March 14

Noon—Box lunch and Old Time Melodrama aboard the Golden Rod Showboat on the Mississippi River.

Effinger Injured, Wife Killed in Auto Crash

R. T. Effinger, assistant chief engineer at Shell Oil Company's Deer Park refinery near Houston was severely injured and Mrs. Effinger fatally hurt in an automobile collision near the refinery October 31. The accident, which happened about 7 pm on State Highway 146, involved the Effingers' car and a car driven by a worker at the Humble Oil & Refining Co. refinery at Baytown, who also was injured seriously.

Mrs. Effinger died at 7:45 pm in the San Jacinto Hospital at Baytown.

The Effinger's live at Route 1, Box 290, La Porte, Texas.

Educational Lectures Set

Three educational lectures will be given during the 13th Annual NACE Conference and Exhibition at St. Louis in March as follows:

March 12: 4:30 pm—Principles and Criteria of Cathodic Protection, M. H. Peterson, Naval Research Laboratory.

March 13: 4:30 pm—Fundamentals of Non-Metallic Coatings for Corrosion Protection, G. W. Seagren, Mellon Institute of Industrial Research.

March 14: 4:30 pm—Fundamentals of Metal Coatings for Corrosion Protection, F. Faust, Battelle Memorial Institute.

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Good Progress Made—

(Continued From Page 112)

Corrosion in Sour Water Stripper, C. M. Schillmoller, International Nickel Co.

Recent Experience With Aluminizing of Reactor Tubes in Catalytic Reformers, Walter S. Jansen, American Oil Co.

Controlling Water Corrosion, Maxey Brooke, Phillips Petroleum Co.

Selection of Materials for Heat Exchangers, Oliver Hatzel, Scoville Mfg. Co.

Stainless Steel in Petroleum Refining, Ed Hildebrand, Humble Oil and Refining Co.

(Subject not announced), Carl Samans, Standard Oil Co. (Ind).

Quantitative Comparison of Surface Finish and Heat Treatment of Stainless Steel With Respect to Corrosion in Jet Fuels, R. G. Carlson.

Corrosion Principles Symposium

Chairman: Walter A. Luce, The Duriron Co., Dayton; co-chairman: Robert C. Weast, Case Institute of Technology, Cleveland.

Pitting Corrosion, H. P. Godard, Aluminium Laboratories, Ltd., Kingston, Ont.

Intergranular Corrosion, W. O. Binder, Electro Metallurgical Co.

Corrosion Inhibitors Symposium

Chairman: George E. Best, Mutual Chemical Div., Allied Chemical and Dye Corp., Baltimore; co-chairman: S. K. Coburn, Association of American Railroads, Chicago.

Statistical Considerations in Evaluation of Corrosion Inhibitors, Charles F. Nathan, The Texas Co.

Adsorption of Sulfonate Corrosion Inhibitors, A. H. Roebuck, Continental Oil Co.

An Evaluation of Inhibitors for Corrosion Prevention In an Engine Cooling System, Leonard C. Rowe, General Motors Corp.

Non-Chemical Factors Governing Selection of Inhibitors for Air Conditioning Systems, Sidney Sussman, Water Service Laboratories, Inc.

Cathodic Protection Symposium

Chairman: Carl R. Johnson, Port of New York Authority, New York; co-chairman: W. E. Huddleston, Huddleston Engineering Co., Bartlesville, Okla.

Cathodic Protection of Naval Reserve Vessels, L. J. Waldron and M. H. Peterson, Naval Research Laboratory

Current Distribution Studies, E. E. Nelson, Naval Research Laboratory.

(Title to be selected), L. P. Sudrabin, Electro Rust-Proofing Corp. and F. W. Ringer, Consultant.

General Corrosion Symposium

Chairman: E. G. Holmberg, International Nickel Co., New York.

Corrosion of Galvanized Sheeting in Contact With Concrete Containing Calcium Chloride, Clarence E. Menge.

Resistance of Aluminum Alloys to Alkaline Building Materials, C. J. Walton, F. A. McGeary and E. T. Englehart, Aluminum Company of America.

Corrosion of Iron by Solid Solutions of Its Sulfides, J. D. Sudbury, Continental Oil Co.

Discoloration of Copper and Brass, Einar Mattsson, A. B. Svenska Metallverken.

Corrosion of Metals in Tropical Environments, Allen L. Alexander, Naval Research Laboratory.

Corrosion by Water, Edmond LeClerc, University of Liege.

(Title to be selected), T. P. Hoar, Cambridge University, England.

Elevated Temperature Corrosion Symposium

Chairman: W. D. Manly, Oak Ridge National Laboratory, Oak Ridge, Tenn.; co-chairman: John Halbig, Armco Steel Corp., Middletown, Ohio.

Oxidation of Molybdenum, J. F. Mosher, E. S. Jones, Rudolph Speiser and J. W. Spretnak, Ohio State University.

Corrosion Resistance of Various Ceramics and Cements to Liquid Metals, W. H. Cook, Oak Ridge National Laboratory.

"Present Status of Oil Ash Corrosion Problems" and "Fused Salt Corrosion" to be presented by authors from General Electric Co. and Battelle Memorial Institute respectively.

Plastics Symposium

Chairman: G. Heinemann, Columbia-Southern Chemical Corp., Corpus Christi; co-chairman: Walter B. Meyer, St. Louis Metallizing Co., St. Louis.

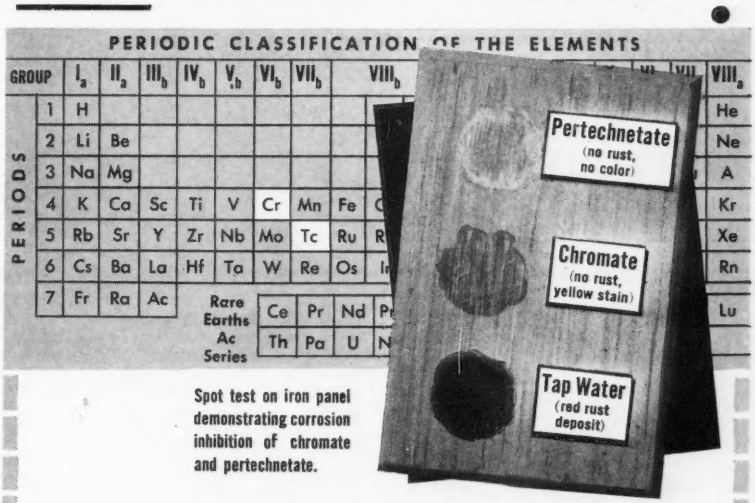
Present Status and Potential Use of Plastic Pipe in the Chemical Process Industry, Raymond B. Seymour, Loven Chemical of California.

Engineering Properties of Rigid Polyvinylchloride, Kenneth A. Phillips, American Zinc, Lead & Smelting Corp.; Walter B. Meyer and Otto H. Fenner, Monsanto Chemical Co.

(Continued on Page 114)

...what is your

best corrosion inhibitor?



Spot test on iron panel demonstrating corrosion inhibition of chromate and pertechnetate.

Recent research* with a very rare man-made metallic element called technetium has shed new light on the mechanism of corrosion inhibition.

Experiments have demonstrated that even in concentrations as low as 5 ppm and at temperatures of 450° F., pertechnetates completely inhibit iron oxidation. But technetium is a synthetic element obtained by bombarding molybdenum with deuterons, or in the fission of uranium as a fission product. As a result it is extremely scarce and prohibitively expensive.

Fortunately, chromates have an ionic structure very similar to that of the pertechnetates, permitting dependable and efficient corrosion control at a tiny fraction of the cost of technetium compounds.

Mutual Chromium Chemicals have been widely used for corrosion control for many years, during which time we have accumulated much useful experience. May we help you with your corrosion control program?

*Sci. Am. 194, 35-39 (May 1956)

Sodium Chromate • Chromic Acid • Sodium Bichromate • Potassium Bichromate • Potassium Chromate

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St. Louis Program Symposia Officials

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Good Progress Made—

(Continued From Page 113)

Present Status of Plastic Vessels in the Chemical Process Industry, John W. Carrow, Haveg, Corp.

Present Status of Plastic Ducts and Stacks in the Chemical Process Industry, Joseph L. Huscher, Kaye-Tex Mfg. Corp.

Pipe Line General Symposium

Chairman: Pearce R. Butterfield, Transcontinental Gas Pipe Line Co., Houston; co-chairman: R. J. Emerson, El Paso Natural Gas Co.

(Continued on Page 116)

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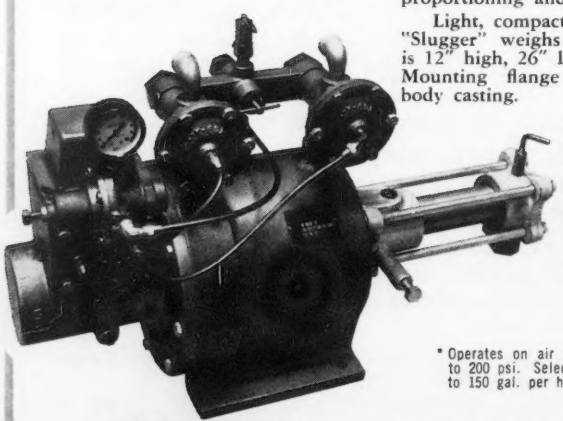
Ideal for slugging corrosion inhibitors, paraffin control or scale control chemicals into high pressure wells or flow lines, due to swift attainment of maximum discharge pressure of 4,000 psi. Also widely used for hydrostatic testing.

A positive displacement type pump, the "Slugger" suffers no loss of volume at high pressures and handles heavy, viscous fluids with ease. Field-proven performance in handling large volumes of additives makes it immensely popular for proportioning and treating.

Light, compact and portable, the "Slugger" weighs only 80 lbs. and is 12" high, 26" long and 11" wide. Mounting flange is integral with body casting.



The "Slugger" pump features high strength aluminum alloy body casting, stainless steel piston and rods, and packing glands which can be tightened externally. All moving parts are lubricated by an enclosed oil bath. Ask today for free literature on Texsteam's complete line of pumps.

* Operates on air or gas pressures up to 200 psi. Selective volumes from 1 to 150 gal. per hr.

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NEW YORK WORLD-TELEGRAM AND SUN, THURSDAY, AUGUST 9, 1956
Phoenix Raises a Big Roof
Also RUSTLESS thanks to ZINC!
Trussless Steel Giant
The erection of the world's largest trussless steel roof, a clear span 120 feet wide and 200 feet long, over the new $750,000 Phoenix Coliseum under construction in Phoenix, Ariz., was announced today by the Wonder Building Corp. of America.
Called the "Wonder Roof," it is the first in a new line of low-cost, long-span custom-engineered roof decks being marketed by the firm for convention halls, arenas, etc. Costs are said to be one-third less than conventional roof structures.
At the Phoenix Coliseum, the unique roof was completely erected in seven and one-half days.
CURVED SHEETS of corrugated steel are fastened together by nuts and bolts to form the self-supporting arches which make up the new trussless steel roof. Workmen above assemble pre-engineered sections.

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Two design features of the roof* of the new Coliseum in Phoenix, Arizona are somewhat unique.

1 . . . the roof is TRUSSLESS, thanks to the use of specially designed curved steel sheets, so assembled as to form a strong, self-supporting arch.

2 . . . the roof is RUSTLESS, thanks to ZINC.

Yes, the roof is galvanized and by the continuous galvanizing process, too, which produces a much better coating . . . a coating that adheres more strongly to the steel and which permits severe forming operations without damage. With this coating the metal appears to 'flow' with the base metal when being shaped.

BUT . . . and this is where St. Joe Electrothermic Zinc enters the picture . . . continuous galvanizing calls for zinc with specially controlled analyses of the other metals. It isn't a question of staying within permissible maximums. It's a question of keeping the other metals within certain specified ranges in order to impart certain desirable characteristics to the zinc and the coating.

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ST. JOE *electrothermic* **ZINC**

ASHAE Meetings Set

The 63rd Annual Meeting of the American Society of Heating and Air-Conditioning Engineers will be held February 25-28, 1957 at Chicago. The 1958 meeting will be held January 27-29 at Pittsburgh.

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Good Progress Made—

(Continued From Page 114)

Power and Communications Symposium

Chairman: W. A. Sinclair, Detroit Edison Co., Detroit; co-chairman: Daniel R. Werner, American Telephone & Telegraph Co., Kansas City.

Corrosion Experience on Pipe-Type Cables in Ontario, R. C. Jacobsen, Hydro-Electric Power Commission of Ontario.

Effect of Pressure on the Corrosion of Feedwater Heater Tubes by Evaporator Vapor Containing Free Carbon Dioxide, M. Decker, Detroit Edison Co.

Electrical Measurements and Their Interpretation in Underground Corrosion Problems, K. G. Compton, Bell Telephone Laboratories.

Woody

(Title to be selected), G. H. Cantwell, Indiana Bell Telephone Co.

High Purity Water Symposium

Chairman: R. U. Blaser, Babcock & Wilcox Co., Alliance, Ohio; co-chairman: W. L. Pearl, General Electric Co., San Jose, Cal.

Statement regarding government sponsored research in field—Introduction.

Measurement of Corrosion Products in High Temperature, High Pressure Water Systems, A. A. Sugalski and S. L. Williams, General Electric Co., Schenectady, N. Y.

Corrosion of Aluminum Jacketed Fuel Elements in Reactor Cooling Water, J. M. Atwood and R. J. Lobsinger, General Electric Co., Richland, Wash.

Corrosion of Aluminum-Nickel Type Alloys in High Temperature Aqueous Service, F. H. Krenz, Chalk River Project, Atomic Energy of Canada, Ltd., Chalk River, Ont.

Storage of High Purity Water, Richard R. Dlesk, Commonwealth Edison Co., Chicago.

Water Conditions for High Pressure Boilers, D. G. Voyles and E. F. Fiss, Duke Power Co., Charlotte, N. C.

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TODD gets ONE-COAT VINYL BUILD with SPEE-FLO hot spray

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Users of the hot spray process for vinyl coatings report up to 300% longer film life, with average material savings of 25%, due largely to reduced overspray. With hot spray, there are no runs and sags; finish is smoother with less orange peel; build, hold-out, and coverage are improved.

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Northeast Region Programs Attract Attention

NORTHEAST REGION CONFERENCE SCENES: Top, Wallace P. Cathcart, Tank Lining Corp., Pittsburgh presents a paper "Suggested Specifications for the Purchasing and Acceptance of Applied Tank Lining Materials" during the Protective Coatings symposium. Center, officials and speakers at Protective Coatings Symposium, left to right, Frank E. Costanzo, Manufacturers Light and Heat Co., Northeast Region chairman; Henry W. Adams, Atlantic Laboratories of Del., Inc., author; T. F. Degnan, E. I. duPont de Nemours & Co., Inc., Philadelphia Section chairman; J. P. G. Beiswanger, General Analine & Film Corp., program chairman and chairman Lehigh Valley Section; J. H. Cogghall, Pennsylvania Salt Mfg. Co., Protective Coatings Symposium chairman; H. H. Bennett, Socony Mobil Oil Co., Inc., Northeast Regional Conference general chairman; W. M. Brackett, Truscon Laboratories, author; Wallace P. Cathcart, author. Left, Wm. H. Aretz, W. A. Briggs Bitumen Co., helps Ginney Stephens, one of Ed Harvey Entertainers entertain at October 16 luncheon.

Philadelphia Sessions Include Meetings of Technical Committees

Especial interest was shown in the symposium on protective coatings at the Northeast Region Corrosion Conference held October 15-17 at Philadelphia. Papers presented on surface preparation, epoxy coatings and specifications for tank lining materials received close attention.

Other sessions devoted to statistical methods, plastics and new alloys and ceramics also attracted substantial audiences.

More than 100 were present for the entertainment program presented by members of the WCAU Ed Harvey Show at the Tuesday luncheon. NACE members and guests added to the merriment by participating in various skits at the request of Ed Harvey. Pete Boyle had an appreciative audience for his story telling at the Wednesday luncheon.

Representatives of ten of the region's twelve sections attended the meeting of the regional board of trustees October 15. F. E. Costanzo, chairman, J. Dwight Bird, vice-chairman and E. L. Simons, secretary-treasurer of the region all were present.

Meetings of committees T-2K, T-4F, TO4F-1 and T-7A also were held Monday.

Assisting Conference General Chairman H. H. Bennett were J. P. G. Beiswanger, E. G. Brink, R. R. Pierce, S. F. Spencer, W. D. Connon, W. H. Aretz, T. F. Degnan, J. C. Bovan, W. H. Burton, J. H. Cogghall, S. I. Croney, J. J. Hur, G. F. Gilbert and J. B. Godshall.

Meters for Underground Tests Are Discussed

Reliable results in making field tests for underground structures can be expected only when the proper meter for the job is being used. A. W. Peabody, Ebasco Services, Inc., New York also told 66 members and guests at a meeting of Chicago Section October 16, particular care must be taken if soil resistance is to be measured accurately. His talk also covered general types of instruments for potential measurements, current measurements, soil resistivity, recording and locating buried structures.

Before the regular business meeting opened L. W. Ewing, Standard Oil Co. (Ind) gave a short illustrated talk about the end products of petroleum, as a feature of Oil Progress Week.

The Fellowship Hour, sponsored by Royston Laboratories, Inc., had Harry Strothman as senior host assisted by L. G. Royston and H. C. O'Brien.

Zinc Institute Moves

American Zinc Institute is now located at 60 East 42nd St., New York N. Y.

Punch Card Service Subscriptions Available

Subscriptions for calendar 1957 issue of the NACE Corrosion Abstract Punch Card service are being accepted now and will be taken through January 15. The rate for a year's subscription is $100 to North American addresses with an additional charge of $7.80 to addresses outside North America for postal insurance.

A limited number of back issues of cards issued during the preceding years of the service are available. About 12,500 cards have been issued through 1956.

New Orleans Selected as Site of 1958 Meeting

New Orleans has been selected as the site of the 1958 meeting of South Central Region, according to W. F. Oxford, Jr., chairman of the region's general meeting committee. The Roosevelt Hotel will be the scene of the event during the week of October 19.

Arrangements for meetings of South Central Region are being considered for Denver in 1959 and Tulsa in 1960, according to information from the region's general meeting committee.

•

CORROSION's Technical Section is indexed annually in December.

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ORLENE* cathodic protection cable is available in sizes No. 8 AWG through No. 4/0 AWG with either copper or aluminum conductor. It is manufactured with polyethylene insulation and poly-vinyl chloride sheath (Type CPS-OR1) for additional mechanical protection and flame resistance; or where desired, with extra-heavy wall, all-polyethylene insulation (Type CPS-OR2) as an alternate to the insulated and sheathed construction. Both are rated at 600 volts for direct burial.

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Technical data on these fine cables is given in Bulletin LH-8M-455, copy of which is available on request.

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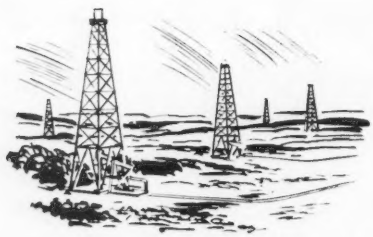

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Central Oklahoma Section Hears Reports on Meeting

The October 30 meeting of Central Oklahoma Section was attended by 21 members. The program consisted of reports on the regional meeting in San Antonio and a talk by John W. Nee, chairman of the region, on "Polyamid Resins—A New Surface Coating Material."

The regular meeting date of Central Oklahoma Section is the fourth Tuesday of each month at the Tropical Cafeteria in Oklahoma City.

ERRATA

September—On Page 98 the price per copy of the American Society for Testing Materials Symposium on Metallic Materials for Service at Temperatures Above 1600 F should be $3.50.

October Pages 83, 84: The company affiliation of Mrs. Renee Korff should have been given as Remington-Rand, Univac Division. Dates of the North Central Region meeting should have been listed as November 15 and 16.

October, Page 3: Performance information in the cutlines descriptive of the tape wrapping machine are: The machine can wrap 2000 feet per hour of 8 through 14-inch pipe.

November—Page 83. The final paragraph in the story headed "Coatings Plan Keyed to Edge-Plane Failure Ratio" should read: After testing 40 coating systems and . . .

NATIONAL, REGIONAL MEETINGS and SHORT COURSES

1957

Mar. 11-15—NACE Annual Conference, Kiel Auditorium, St. Louis, Missouri.

May 20-22—Northeast Region Corrosion Control Conference, Syracuse University, Syracuse, N. Y.

1957

October 1-4—South Central Region, Oklahoma City, Okla., Skirvin Hotel.

October 7-9—Northeast Region fall meeting. Pittsburgh, Pa. Penn-Sheraton Hotel.

1958

Mar. 17-21—NACE Annual Conference, Civic Auditorium, San Francisco, California.

1958

October 20-24—South Central Region, New Orleans, Roosevelt Hotel.

1959

NACE Annual Conference, Sherman Hotel, Chicago, Illinois.

SHORT COURSES

January 31-February 1—Houston Section. University of Houston.

April 2-4—University of Oklahoma, Norman and Central Oklahoma Section NACE.

Three Discussion Sessions Planned for St. Louis

Discussion sessions scheduled during the 13th Annual NACE Conference and Exhibition at St. Louis March 11-15 are:

Pipe Line Group Discussions—Chairman: Charles L. Woody, United Gas Corp., Houston; co-chairman: M. A. Riordan, Rio Engineering Co., Houston.

General Corrosion Problems Roundtable—Chairman: A. H. Roebuck, Continental Oil Co., Ponca City, Okla.

Pipe Line and Underground Corrosion Problems Roundtable—Chairman: O. W. Wade, Transcontinental Gas Pipe Line Corp., Houston.

AIChE Meetings Planned

Meetings have been scheduled by the American Institute of Chemical Engineers as follows:

December 9-12—Annual meeting, Statler Hotel, Boston.

March 3-6—Greenbrier Hotel, White Sulphur Springs, Va.

June 9-12—Olympic Hotel, Seattle, Wash.

September 15-18—Lord Baltimore Hotel, Baltimore, Md.

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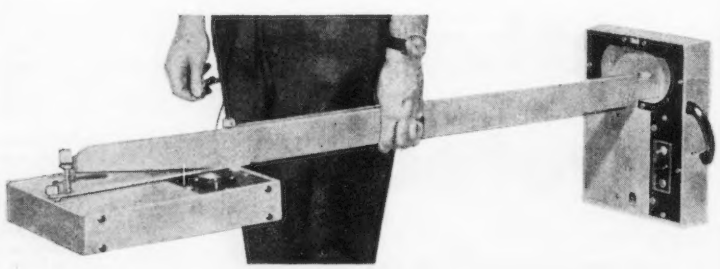

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NACE MEETINGS CALENDAR

Dec.

3 North Texas Section. Design for Corrosion Control, F. L. Whitney, Jr., Monsanto Chemical Co., at Dallas.

5 New England Section. Corrosion in the Home, J. T. Kemp, American Brass Co.

6 Pittsburgh Section. Corrosion of Metals, W. Z. Friend, The International Nickel Co., Mellon Institute.

6 Sabine-Neches Section. My Corrosion Problem of the Year, a panel discussion. Little Mexico Restaurant, Orange, Texas.

13 Philadelphia Section. F. L. LaQue, The International Nickel Co., Inc. scheduled speaker. Poor Richard Club, Philadelphia.

13 Detroit Section. Sprayed Coatings—Metallic and Non-Metallic, R. J. McWaters, Metallizing Engineering Co., N. Y.

19 Greater Boston Section. Vernon Pike, Bell Telephone Laboratories, Protection of Underground Cable Against Corrosion. Hotel Beaconsfield.

Jan.

3 Pittsburgh Section. Mid-East Pipe Line, L. P. Sudrabin, Electro Rust-Proofing Corp. at Mellon Institute.

7 North Texas Section. Hans Brinker, A. O. Smith Corp., on glass lined vessels (Tentative).

9 Central Oklahoma Section.

10 Niagara Section. Stress Corrosion. Business meeting.

15 Chicago Section. J. R. Spraul, General American Transportation Company, East Chicago, Ind., Corrosion Problems in Transportation Vehicles.

17 Kanawha Valley Section. John J. Halbig, Research Laboratories, Armco Steel Corp., Middletown, Ohio.

21 Lehigh Valley Section. A discussion of paint by Francis Scofield. Keystone Trail Inn, Allentown, Pa.

24 Sabine-Neches Section. Metallurgist's Approach to Corrosion. Little Mexico Restaurant, Orange, Texas.

24 Detroit Section. A. J. Thompson, Allis-Chalmers Mfg. Co., Milwaukee, Cavitation and Impingement Attack in Pumps. Dinner meeting.

Llewellyn G. Tubbs

Llewellyn G. Tubbs, research chemist with Barium Reduction Corp., South Charleston, W. Va. was killed in an automobile accident October 6. Mr. Tubbs, who was active in corrosion control work for 26 years was interested especially in the application of hexavalent chromium compounds and problems associated with electrodeposition. He joined NACE in May, 1953.

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A chronological list of all articles published in CORROSION's Technical Section 1945-54 may be found in the 10-Year Index to CORROSION.

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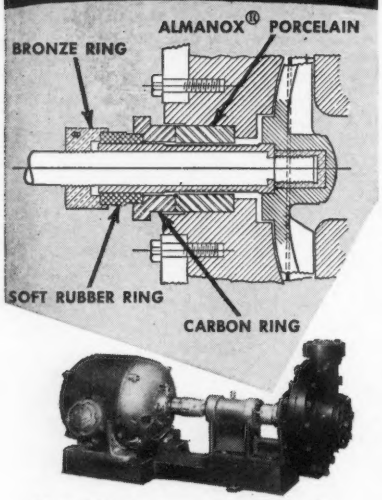

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Greater Boston Section To Hear Pike on Cables

Vernon Pike, Bell Telephone Laboratories is scheduled to speak on Protection of Underground Cable Against Corrosion at a December 19 meeting of Greater Boston Section. The meeting will be held at Hotel Beaconsfield.

Other meetings scheduled by the section are:

February 20—F. L. LaQue, The International Nickel Co., Inc., "Design Against Corrosion." Hotel Beaconsfield.

May 15—Linwood Eikren, Baird Associates, "Spectrographic Analysis to Detect Corrosion." Hotel Beaconsfield. Election of officers.

At the September 19 meeting of the section Francis J. Honn, M. W. Kellogg Co. spoke on "Fluorocarbon Organic Coatings." The film, "The World That Nature Forgot," was shown through courtesy of Monsanto Chemical Co.

Southwestern Ohio Section Tours Battelle Institute

A tour of Battelle Memorial Institute followed by a dinner meeting featured the October 30 meeting of the Southwestern Ohio Section. Approximately 50 members and guests attended.

An afternoon inspection trip of Battelle Memorial Institute covered its new nuclear facilities and an inspection of its corrosion testing facilities. This was followed by an inspection of the metallurgical testing facilities at Ohio State University.

The dinner was held at the Union building of Ohio State University with a coffee talk concerning his recent trip to Aruba, Dominican Republic and Haiti by M. G. Fontana. Dr. Fontana's talk was followed by papers on "Corrosion Problems Involved in Nuclear Reactors" by Warren E. Berry and Walter K. Boyd, project managers at Battelle Memorial Institute.

Volume 12 Corrosion Index Changes Made

The Tabular Topical Index, a feature of CORROSION's annual index since 1950, will not be published for Volume 12. Deletion of the index followed a decision to continue an alphabetical subject index to material in the Technical Section started in 1950. Also dropped from the index to Volume 12 were the collected tables of contents of the Technical Committee Activities section and its related table indexing articles by committees.

The index to Volume 12, in this issue of CORROSION will include collected tables of contents of the Technical Section for the 12 issues; an alphabetical subject index to articles in the Technical Section and an alphabetical author index.

Reports of NACE technical committees not included in the accumulative numbers of the technical section have been appended to the tables of contents.

Comparisons of content between issues published in 1955 and 1956 follow:

Technical Section	1955	1956
Articles	93	105
Authors	230	185
Discussions	143	62
Pages	554	652

Western Region—

(Continued From Page 106)

Corrosion of Concrete by Autotrophies, C. W. Beardsley, Los Angeles Bureau of Standards.

Corrosion in Light Oil Storage Tanks, E. H. Tandy, Standard Oil Co. of California.

Corrosion Experiences in a Mixing Nozzle for Dilute Sulfuric Acid, W. E. Gibson, Shell Chemical Co.

Determination of Corrosion Rates in a Variety of Different Processes by Means of the Corrosometer, G. H. Rohrback, Crest Instrument Co.

November 16

New Developments in Plastics, Lester Morris, Coating & Fiberglass Research Co., program co-chairman.

Properties of Thermoplastic Pipe, Paul M. Elliott, Naugatuck Chemical Co.

Factors of Successful Plastic Applications, Wm. Bartlett, Parker Engineering Co.

Product Data and Field Service Data on Reinforced Plastic Pipe, H. D. Boggs, The Fibercast Corp.

Technical Committee Reports

Reports by NACE technical committees were scheduled as follows:

Corrosion in Oil and Gas Well Equipment—Harry J. Kipps, General Petroleum Corp., T-1A chairman.

Pipe Line Corrosion—L. P. Sudrabin, Electro Rust-Proofing Corp., T-2 chairman.

Coal Tar Coatings for Underground Use—W. F. Fair, Jr., Koppers Co., T-2G vice-chairman.

Utility Industry Corrosion Problems—I. C. Dietze, City of Los Angeles, T-4 chairman.

Corrosion Problems in Process Industries—W. G. Ashbaugh, Carbide and Carbon Chemicals Co., T-5 chairman.

Protective Coatings—L. L. Whiteneck, Plico-Flex Corp., T-6 chairman.

Organic Coatings and Linings for Resistance to Chemical Corrosion—C. G. Munger, Amercoat Corp., T-6A vice-chairman.

Protective Coatings Application Problems—Ivan Sullivan, Spence and Sullivan Co., T-6J chairman.

How Corrosion Is Indexed

1. Alphabetical subject and author indexes are published in December.
2. Abstracts of Technical Articles appear in the Corrosion Abstracts Section.
3. Abstracts of articles appear in NACE Bibliographic Surveys of Corrosion.
4. Abstracts of articles are published in the NACE Corrosion Abstract Punch Card Service.
5. Corrosion is indexed regularly by Engineering Index.
6. A ten-year alphabetical subject and author index (1945-54) has been published and is available now.

British Corrosion Group Schedules 8 Meetings

BOOK REVIEWS

Copper Removal. 6 pages, 8½ x 11 inches, paper. October, 1956. Dowell, Incorporated, Box 536, Tulsa, Okla. Free.

Results of tests conducted by Dowell to find an agent that could be used to remove copper deposits from boilers in the same stage with water-formed deposits are detailed. A complexing agent was found which does not interfere with the other agents in boiler cleaning compounds and which does not aggravate the rate of acid attack on metal unduly. Field trials indicate results achieved in laboratory tests are substantially duplicated in utility and industrial boilers.

Progress in Nuclear Energy. Series IV —Technology and Engineering. 420 pages, 6 x 9, cloth. 1956. R. Hurst, AERE Harwell; S. McLain, Argonne National Laboratory, editors. McGraw-Hill Book Company, Inc., 330 West 42nd St., New York 36, N. Y. Per copy $12.

This is the fourth in a series of eight topics related to nuclear energy technology. The book is divided into sections: Heavy water, graphite, beryllia, liquid metals, engineering, reactor chemistry and corrosion. Contributors active in each of the several fields have contributed articles on the subjects listed.

In the section headed Reactor Chemistry and Corrosion titles of articles are: Radiolytic Behaviour of Water in a Nuclear Reactor, Pressurized Water Reactor (PWR) Water Chemistry, Survey of Homogeneous Reactor Chemical Problems, Aqueous Uranium and Thorium Slurries, Aqueous Corrosion of Zirconium and Its Alloys at Elevated Temperatures, Corrosion by Liquid Metals and Metallurgical Studies on Liquid Bismuth and Bismuth Alloys for Reactor Fuels or Coolants. Each article has an appendix of references. There is an alphabetical subject index.

Corrosion—A Symposium. 609 pages, 5⅜ x 8½ inches, cloth. 1956. A. F. Dunbar, L. M. Clareborough and H. A. Stephens, publications subcommittee. The Committee of the Symposium on Corrosion, Metallurgy School, University of Melbourne, Carlton N. 3, Victoria, Australia. Per copy, 2 Pounds, 10 Shillings.

Papers presented during the symposium held at the Engineering School, University of Melbourne, Nov. 28-Dec. 2, 1955.

The book is divided into three sections: Fundamentals, Prevention and Corrosion in Industry. The first section includes 10 articles on various problems related to fundamental corrosion processes and testing methods. The section on prevention includes eight papers on coatings, inhibitors, cathodic protection, ship corrosion and external corrosion of gas mains and services. The third section has papers on aircraft, chemical, gas, paper, petroleum and power industry corrosion problems.

Symposium on High Purity Water Corrosion. 56 pages, 6 x 9 inches, paper. ASTM Special Pub. No. 179. 1956. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy, $1.75.

Papers presented during the ASTM June, 1955 meeting at Atlantic City. The symposium was sponsored by Committee D-19 on Industrial Water. Titles of papers are: Preparation and Maintenance of High-Purity Water, F. N. Alquist; Use of Water in Atomic Reactors, H. W. Huntley and S. Untermeyer; Influence of Water Composition on Corrosion in High-Temperature, High-Purity Water, Donald M. Wroughton, James M. Seamon and Paul E. Brown; Effect of Materials Composition in High Temperature Water Corrosion, A. H. Roebuck; Special Corrosion study of Carbon and Low Alloy Steels, R. U. Blaser and J. J. Owens. Discussions are included.

Water Research News Publication Is Started

A bulletin designed to ensure a close connection between the Water Research Association of England and water undertakings titled "Water Research News" has been issued. The periodical is published by the association at 18 Linkfield Lane, Redhill, Surrey, England. Vol. 1, No. 1 was published in September, 1956.

Included are reviews of technical publications by the association, including "A Note on the Treatment of Aggressive Water by Aeration." Other information is included on "Permeability of Polythene to Coal Gas," relating experience in which gas from a leaking pipe tainted water in an adjacent plastic pipe line.

An article giving basic information on cathodic protection tells of the formation of the Joint Committee for the Coordination of the Cathodic Protection of Buried Structures, which has as members the British Transport Commission, Central Electricity Authority and Area Boards, Gas Council, General Post Office, United Kingdom Pipelines and the Water Research Association.

Engineer, Physical Science Examinations Scheduled

Civil Service examinations for engineer and physical science positions in activities of the Potomac River Naval Command in and near Washington and the Engineer Center, U. S. Army, Fort Belvoir, Va. have been announced. Applications may be filed with the Board of U. S. Civil Service Examiners for Scientific and Technical Personnel, Potomac River Naval Command, Building 72, Naval Research Laboratory, Washington 25, D. C. Salaries range from $4480 to $11,610 a year.

Corrosion of Metals In Buildings Is Topic Of March Session

Meetings of the Corrosion Group of the Society of Chemical Industry have been scheduled as follows:

January 9—Corrosion Problems in Nuclear Power Production, A. B. McIntosh. Society of Chemical Industry, London.

January 24—Conversazione. Members are invited to submit exhibits illustrating their researches. Battersea Polytechnic.

February 20—Theory and Practice in Potential Measurements for Cathodic Protection, P. W. Heselgrave. Society of Chemical Industry, London.

March 21—Symposium on Corrosion of metals in Buildings:

Resistance to Corrosion of Non-Ferrous Metals in Buildings, F. E. Jones.

Corrosion of Ferrous Metals in Buildings, J. C. Hudson and F. Wormwell.

Corrosion of Metals in Contact With Concrete, P. E. Halstead.

Aluminium Cladding of Buildings, E. H. Laithwaite and E. W. Skerrey.

Performance of Zinc and Zinc Coatings in Buildings, S. Baker and E. Carr.

Joint meeting with Road and Building Materials Group.

April 3—Protection of Structural Steel Against Corrosion. J. C. Hudson. The Technical College. Joint meeting with South Wales Section.

April 8—Spring Lecture: Corrosion Researches of Professor Piontelli and his associates at Milan, R. Piontelli. Society of Chemical Industry, London.

May 7—Annual general meeting and chairman's address: A Pilgrim's Progress from Corrosion, T. H. Turner. Society of Chemical Industry.

May 8—Education panel annual general meeting. Society of Chemical Industry, London.

Plastics Technical Session Papers to Be Delivered

Among the papers scheduled for delivery during the Society of Plastics Engineering, Inc. during its Thirteenth Annual National Technical Conference in St. Louis January 16-18 are:

Permeability of the Polyethylenes to Gases and Vapors, V. T. Stannett, Professor of Polymer Chemistry, State University of New York, Syracuse.

Plastics Sandwich Construction, G. D. Miller and H. J. Waite, Dow Chemical Co., Midland, Mich.

Rigid Thermoplastic Piping, R. K. Multer, Carbon Chemical Div., Borg-Warner Corp.

Synthetic Fiber Reinforcement of Thermosetting Resin Laminates, John G. Green, Jr., Textile Fibers, Dept., E. I. duPont de Nemours & Co., Inc.

•

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Strength-Time Behavior of Plastics on SPI Agenda

Strength-time behavior of reinforced plastics will be the topic of first day's sessions at the February 5-7 12th Annual Technical and Management Conference of the Reinforced Plastics Division of the Society of the Plastics Industry, Inc. The meeting will be held at the Edgewater Beach Hotel, Chicago.

Further discussions on strength-time behavior will be held on the second day as well as sessions on engineering design and processing, developments in foreign countries, and others. The third day will cover glass and finishes, and an open forum, among other topics.

ASME Program Includes Boiler Feedwater Papers

On Friday, November 30 during the American Society of Mechanical Engineers annual meeting in New York the Symposium on Boiler Feedwater Studies (II) listed the following papers:

The Use of Bureau of Mines' Condensate-Corrosion Testers for Survey of Return Line Deterioration, Abraham A. Berk, Bureau of Mines.

Steam Purity Studies Comparing Sodium and Conductivity Methods, Chester A. Bishof, J. Kenneth Brown and Lewis J. Kahler, W. H. & L. D. Betz.

Selecting Water Treating Processes for Medium Pressure Boilers, R. J. Zumbrunnen, Scott Paper Co., and Samuel B. Applebaum, Cochrane Corp.

Refractory, Hard Metals Symposium Is Presented

Papers presented in the Refractory and Hard Metals Symposium, a feature of the dedication ceremonies September 18 at Union Carbide and Carbon Corporation's Parma, Ohio research laboratory were:

Some Fundamentals Concerning High Temperature Materials, Prof. R. Smoluchowski, Carnegie Institute of Technology, Pittsburgh.

Predicting the Thermodynamic Stabilities and Oxidation Resistance of Silicide Cermets, Prof. Alan W. Searcy, Ceramic Laboratories, Div. of Mineral Technology, University of California, Berkeley.

Problems of Defense Are Referred to Inventors

The Department of Defense has assigned 35 new technical problems for the attention of civilian inventors to the National Inventors Council, U. S. Department of Defense, liaison agency between inventors and the armed forces. The problems, ranging through the fields of aeronautics, electronics, mechanics, plastics, chemistry, instrumentation, materials handling and others are published in a supplement to the council's cumulative list, "Technical Problems Affecting National Defense." The list and supplement are available by writing to NIC, U. S. Dept. of Commerce, Washington, D. C.

Tobacco Smoke Statistics

The Los Angeles Air Pollution Control District estimates that tobacco smokers add 12 tons of contaminants to the air of the county every day.

The district also counts 65,000 people more in the county this year than last, which means thousands more automobiles and expanded industrial operations.

Rapid growth of car pools, recommended by the Los Angeles Chamber of Commerce to reduce the number of automobiles in use and thereby reduce exhaust contamination, has been reported.

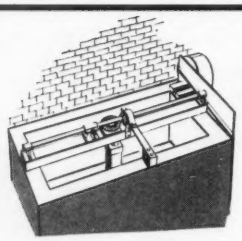
British Pipeline Magazine

"Pipelines and Pipes for Building, Commerce and Industry," published at Holland House, 140 Cromwell Road, London S. W. 7 is a periodical designed to "disseminate to widest possible circle of users and potential users of pipes in building, commerce and industry the technical knowledge that modern developments have made available."

Vol. 1, No. 1 includes articles on pipeline surveys and planning, plastic pipes and tubing, pipes for nuclear power, flexibles and other departments.

Battelle Has Reactor

Gamma rays and neutrons produced by Battelle Memorial Institute's water bath reactor recently activated will be used for atomic research in the chemistry of petroleum, sterilization of pharmaceutical products, preservation of agricultural goods and improvement and development of numerous materials of construction and processes.



After 5 years
TOREX® ENAMEL
still protects alum tanks
AT Celanese
CORPORATION OF AMERICA

Alum solution in the concrete tanks at Water Filter Plant, Celanese Corporation, Belvidere, N. J., was eating through the concrete and loosening the mortar in the brick wall behind the tanks. That was back in 1951. Celanese engineers consulted Inertol Co., Inc., manufacturers of specialized coatings. Inertol®s Torex Enamel was used.

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Torex Enamel is a chlorinated natural rubber-base coating, in color. It's easily cleaned, resists water-treatment chemicals. Today, send for free informative folder, "Inertol Chemical-Resistant Enamels" C-571. No obligation. Write your name, title, firm name and address in margin of this page and mail.

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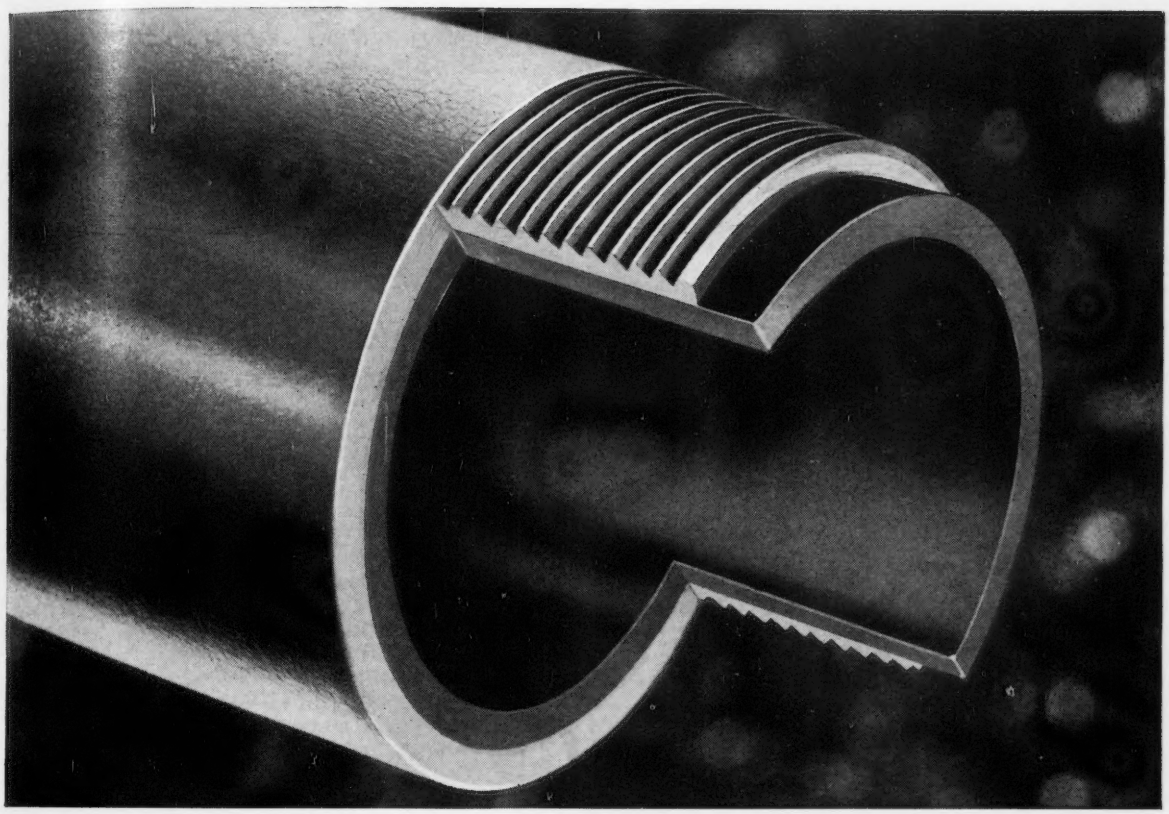

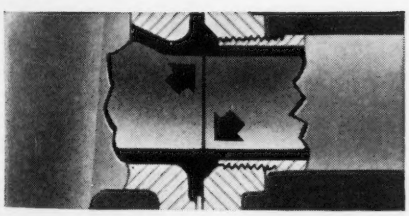

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Equipment Services NEW PRODUCTS Materials Literature

General Electric Company has developed vacuum tubes, capacitors, resistors, transformers, inductors, wires, printed circuit boards and an electric motor which continue to function at temperatures ranging from 900 to 1500 F.

•

Chemtrol Corp., 11008 Santa Fe Ave., Lynwood, Cal. is producing a line of polyvinyl chloride valves designed to operate continuously up to 170 psi continuously and at temperatures up to 170 F in lower pressure systems. Sizes are ⅛ and ¼-inch pipe sizes and ⅛, ¼ and ⅜-inch OD male tube connections. Needle and globe designs are available. A Kel-F needle is used and a Teflon O-ring is applied in the globe valves.

•

Tungsten and Chemical Division of Sylvania Electric Products Inc. has started a new engineering and pilot building at Towanda, Pa. to house over 100 scientists, engineers and technicians.

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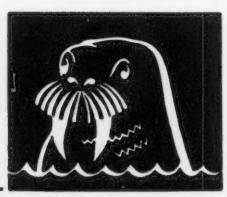

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☐ NERVA-PLAST technical bulletin

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Cook Technological Center, designed for a staff of more than 1000 has been opened by Cook Electric Company in Morton Grove, Ill., a suburb northwest of Chicago. Seven air conditioned buildings on a 15-acre tract are included as is a heliport and parking for 1200 cars.

•

Napko Corporation has moved into its 60,000 square foot new plant on an 8-acre site at 5300 Sunrise Street, Houston. The four units on the site include facilities for manufacture of the company's coatings lines, which range from the decorative to high performance industrial. A catalytic combustion chamber, plus advanced systems of washing are used to control fume emission.

•

Porcelox, a water-base, inorganic, semi-porcelain ceramic coating recommended by Kraus Research Laboratories, Cockeysville, Md. as a protective coating for surfaces subjected to heat up to 1100 F is available in experimental quantities at nominal prices. The coating may be brushed, sprayed or dipped, is available in black, dark green or in graphited formulation for sliding surfaces. After air drying curing is effected by baking at 450 F for 15 minutes or longer dependent on subject mass. Thin gauge elements such as automobile exhaust manifolds and fire doors may be cured automatically by heating in use. The material is incompatible with organic paints, is not recommended as a paint base and should not be used where strong acids and alkalis are in the environment.

•

Labline-Pure Corrosion Tester, basically a sensitive Wheatstone Bridge circuit, permits predictions of probable corrosion damage to metals in liquids or gases. Tests of only a few hours' duration permit predictions that may take place in five or ten years' field use, according to Labline, Inc., 3070-82 West Grand Ave., Chicago 22, Ill. The device consists of a probe supporting one strip of material to be tested exposed to the environment and another protected from it. Corrosion of the exposed strip, indicated on a meter in micro-inches, gets automatic temperature compensation from the protected strip. Suggested applications include determining characteristics of gasoline additives; of oil additives; and of rust inhibitors designed for addition to the water phase in cooling cycles. More information is available in Bulletin No. 5200 available from the company on request.

•

Tubular Lining Corporation has started construction of a plant designed to produce baked phenolic linings on about 5000 feet of tubing per working shift. L. E. Heinen, president and founder of the company, said the plant, to be located in the 12200 block of Robin Boulevard, off Almeda Road, near Houston, will be equipped with the latest automatic equipment to clean, coat, bake and test tubing. Production is expected to begin about December 20.

•

Fabrication of Low-Nickel, High-

(Continued on Page 128)

A BELL RINGS

When it finds a "holiday" in any dielectric pipe coating.

† U. S. Patent No. 2,629,002
* Patents Pending

Model H-P

HOLIDAY DETECTOR Without Ground Wire, for Use on Transmission Lines.

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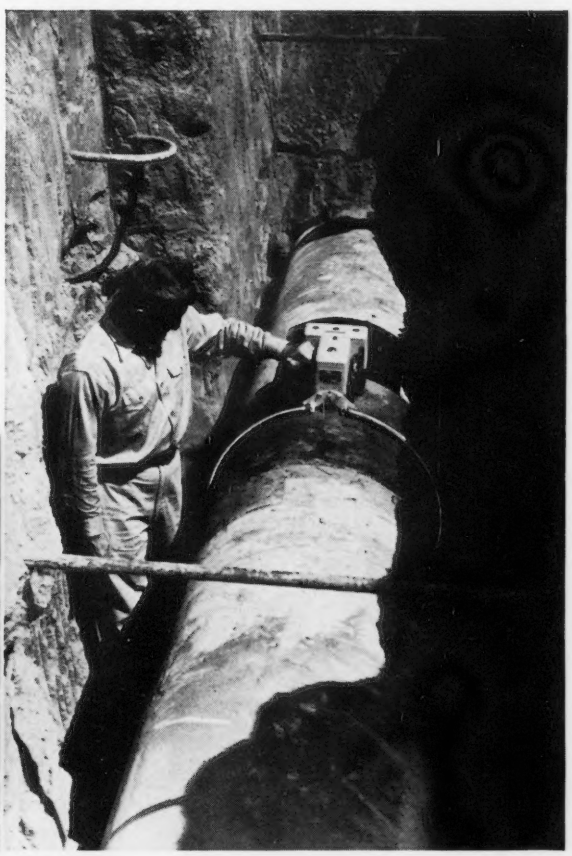
This H-P Tinker & Rasor Holiday Detector rings the Bell two ways: the first is actual. As you roll it easily along the pipe (it weighs only 23 pounds), a bell will sound and a light will flash if the tiniest pin-hole or coked spot is found in the protective wrapping on the pipe. By means of a rolling spring electrode† (detachable from the detector from either side) the pipe is completely encircled and no spot on its surface is missed. Hundreds of feet of line pipe can be covered in a short time and inspection of field joints or patches are easily made, even in the ditch.

It rings the bell for simplicity too. Because it uses a new-principle, double electrode, pad or "saddle,"* it maintains a constant inspection voltage of 12,000 to 15,000 volts on the pipeline at all times and no trailing ground wire is needed. Weather and soil conditions do not affect its operation. No generator is needed as the detector carries its own 3-cell, storage battery in a shock resistant Royalite case resting on a phenolic plastic base. It does not utilize a "hot" spark which can damage coatings.

Works equally well on damp or dry coatings



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NEW PRODUCTS

(Continued From Page 126)

Manganese Stainless Steels, an 8-page reprint from May, 1956 METAL PROGRESS is available from The International Nickel Co., Inc., New York 5, N. Y., Reader Service Section. The new 200 stainless steels are compared with standard 18-8 steels.

•

Duracron, a family of coatings based on a new series of thermo-setting acrylic resins is available in a complete range of colors from Pittsburgh Plate Glass Company's Industrial Finishes Division. The resins are superior to alkyd-melamine resins, according to tests conducted by the company, in that they have better color and gloss retention on overbake; chemical and detergent, humidity and salt spray, grease and stain, and impact resistance as well as flexibility and mar resistance.

•

High Purity distilled water from sea water with less than ¼ grain per gallon total solids is produced by a 4-stage flash distilling plant developed by Badger Manufacturing Co., Cambridge, Mass. A 1000-gallon-per-hour unit has been operated at the Inco Kure Beach Test Station for over a month at well over capacity. Designed to operate on low or high level waste heat, the unit is compact, with pumps as the only moving parts. The manufacturers claim scale free, completely automatic action is possible.

Ductile Cast Iron pipe fittings manufactured by Kuhns Brothers Company, 1800 McCall St., Dayton 1, Ohio have been tested and proved superior to gray cast iron in strength, pressure tightness and their ability to resist stretching on screwed joints. This improved strength has permitted designing lighter fittings for use where weight is a factor. More information is in Catalog 1, available on request from the company.

•

Titanium Strip in thicknesses down to 0.001-inch is being made by American Silver Company, Inc., 36-07 Prince St., Flushing 54, N. Y. It is intended for use in lightweight honeycomb structures subjected to heats under 700 F.

•

Silastic LS-53, a synthetic, low-swell, heat resistant chemical hybrid of silicone and fluorinated plastic is now being produced by Dow Corning Corp., Midland, Mich., for use in jet powered planes. It is used in O-rings and seals where it is in contact with gasoline, jet engine fuels, hydraulic fluids and engine oils at temperatures between —280 to over 400 F.

•

Hi-Cor, a solder flux for use in non-electrical applications has been developed by Alpha Metals Inc., 56 Water St., Jersey City 4, N. J. Manufacturers claim the new flux is suitable for operations where only small amounts of corrosion can be tolerated.

•

Nucledyne Corp., 1457 Diversey Parkway, Chicago has been organized as a wholly owned subsidiary of Cook Electric Company. The corporation will specialize in engineering, design and installation of environmental testing equipment, radiation test facilities and similar projects. The company expects to be of particular service in nuclear application and space flight research programs.

•

Cealment, a latex-cement slurry for well-cementing operations and a stabilized acid which contains an agent to prevent reprecipitation of iron deposits are described among others in new literature available from Dowell, Inc., Box 536, Tulsa, Okla.

•

Polyethylene spheres about 1½ inches in diameter are used in a blanket of about 55 spheres per square foot to cover the surface of an open acid plating tank and prevent fumes and splashes that normally occur. The spheres are made by Cosom Industries, Inc., Minneapolis, Min. from Bakelite polyethylene.

•

Platinum Bonded tungsten carbide is now being used by Kennametal, Inc., Latrobe, Pa. to make bushings, metering orifices and seal rings for nitric acid systems, among other uses, in the chemical industry.

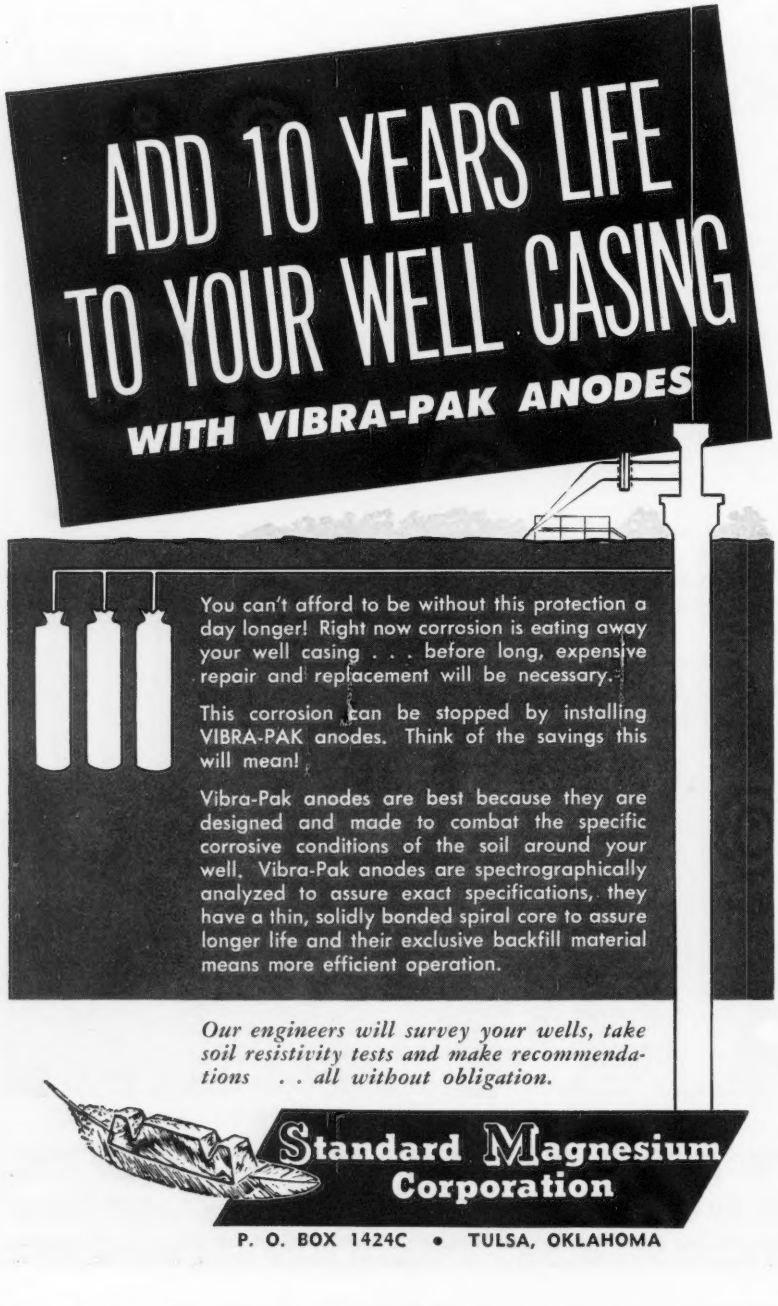
•

Seidel Calculating boards available from Jarrell-Ash Company, 26 Farwell St., Newtonville 60, Mass. are described in a bulletin available from the company. The boards can be used to construct spectrographic emulsion calibration curves and transform the usually encountered logarithmic curves into easily interpreted, nearly straight lines.

•

Quantum, Inc., 756 N. Brooksvale Rd.,

(Continued on Page 129)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Our engineers will survey your wells, take soil resistivity tests and make recommendations . . . all without obligation.
Standard Magnesium Corporation
P. O. BOX 1424C • TULSA, OKLAHOMA

NEW PRODUCTS

(Continued From Page 128)

Cheshire, Conn. has developed the Quantum Ellipsometer, a polarizing spectrometer that can measure directly the thickness of films which can be deposited on suitable substrates in the range of from several to many hundred Angstroms. It is useful in measuring thickness of films such as lubricating agents, surface coatings and adhesives.

•

Resin Research Laboratories, 406 Adams St., Newark 5, N. J. was host October 15 to the advanced class of Rutgers University entitled "Laboratory Techniques and Latest Developments in Coating Technology," conducted by William Lawrence.

•

Fisher Research Laboratory, Inc., 1961 University Ave., Palo Alto, Cal. is making a battery operated vacuum tube millivoltmeter especially designed for field use in measuring the small potentials involved in corrosion processes. Essentially infinite input resistance, 10 megohms, on all ranges provides minimum disturbance to the circuit under test, the manufacturer says. Six full scale ranges between 0-25 and 0-100 millivolts and two additional ranges 0-10 and 0-100 volts are provided. Scale divisions on the 0-25 millivolt scale make measurements of 50 microvolts possible. It is available in both DC and AC models. Accuracy is plus or minus 1½ percent on all ranges. It weighs five pounds in leather carrying case.

•

Central Foundry Company is expanding its cast iron soil pipe plant at Holt, Alabama.

•

Minneapolis-Honeywell Regulator Company will build a 3-acre plant for its valve division at Fort Washington, Pa. The valve division presently is located in Philadelphia.

•

Hokin Aluminum Company's extrusion plant near Chicago has been acquired by Kaiser Aluminum and Chemical Corp.

•

Babcock & Wilcox Co. will design and engineer a nuclear research reactor for Kernenergie Hamburg, the Society for the Utilization of Nuclear Energy in Shipbuilding and Navigation, Inc., of Hamburg, Germany.

•

Primers recently developed in Bakelite Company laboratories greatly improve adhesion of vinyl chloride type resin coatings to metal surfaces. They are of special interest with vinyl dispersion coatings. Adhesion of organosol and plastisol systems used with these primers over metals is excellent and does not fail under steam sterilization and high humidity.

•

Titanium produced by Titanium Metals Corp of America, 233 Broadway, New York 7, N. Y. will be rolled and forged in the plant formerly owned by Louis Berkman Company at Toronto, Ohio. It will be the first effort to handle the metal in a separate plant. Formerly all rolling of titanium has been done on steel mill facilities. Total consumption of titanium mill products for 1958 is predicted at 30 million pounds.

Ceramic coatings on mufflers were credited with extending their service life to more than 300,000 miles in some instances by Richard Crumley, Toledo Porcelain Enamel Products Co., a division of The Bettinger Corp., Waltham, Mass.

•

Forged Rings for large flanged openings of glass-lined process vessels are made by Standard Steel Division, Baldwin-Lima-Hamilton Corp.

•

Jet-Set, a new enamel primer developed by Koppers Company, Inc. is designed for conditions where fast drying is important. Where conventional enamel primers may take from 12 to 24 hours to dry completely enough for application of enamel, Bitumastic Jet-Set is ready for enameling in about one hour, the company says. In cold weather and under adverse weather conditions Jet-Set will dry in eight hours or less, compared to five days or longer for conventional enamels under the same conditions. It can be applied by brush or spray with a coverage of between 400 and 500 square feet per gallon. Complete technical data is available from Tar Products Division, Koppers Co., Inc., Pittsburgh, Pa.

•

Sloane Manufacturing Co., 12270 Mon-

(Continued on Page 130)

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NEW PRODUCTS

(Continued From Page 129)

tague St., Pacoima, Cal. makes globe-type valves of butyrate plastic.

•

Polyken Industrial Tapes will be produced at a new 35,000-square-foot, $1.3 million dollar plant now under construction at Franklin, Ky. It also will produce plastic film and plastic specialties, tripling the company's capacity for these products now made in Chicago.

•

Tanks and Pipes in Dow Chemical Company's 18,000-ton S.S. Marine Dow-Chem which carry liquid caustic are lined with more than 100,000 pounds of nickel. The vessel, believed to be the first vessel protected inside and out from corrosion, was inspected at a Brooklyn drydock by shipping firm executives. The hull and wing ballast tanks are cathodically protected by magnesium anodes. Tanks holding hydrochloric acid are lined with rubber.

•

Grove Valve and Regulator Co. and Grove Controls, Inc., both of Oakland, Cal. have been acquired by Walworth Co.

•

An Aluminum batten-type roof is being installed on the Carnegie Institute and Library at Pittsburgh. It will weigh slightly less than a pound per square foot compared to 8.5 pounds per square foot for the former tile covering.

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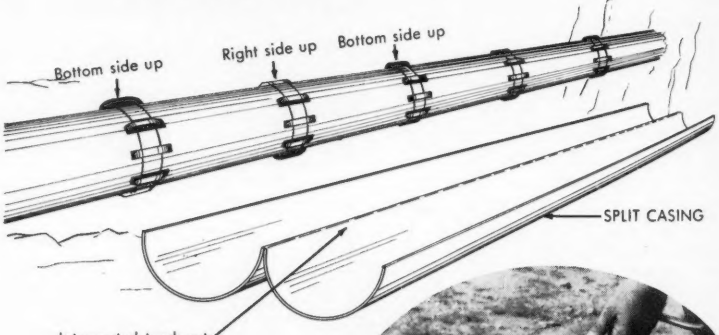

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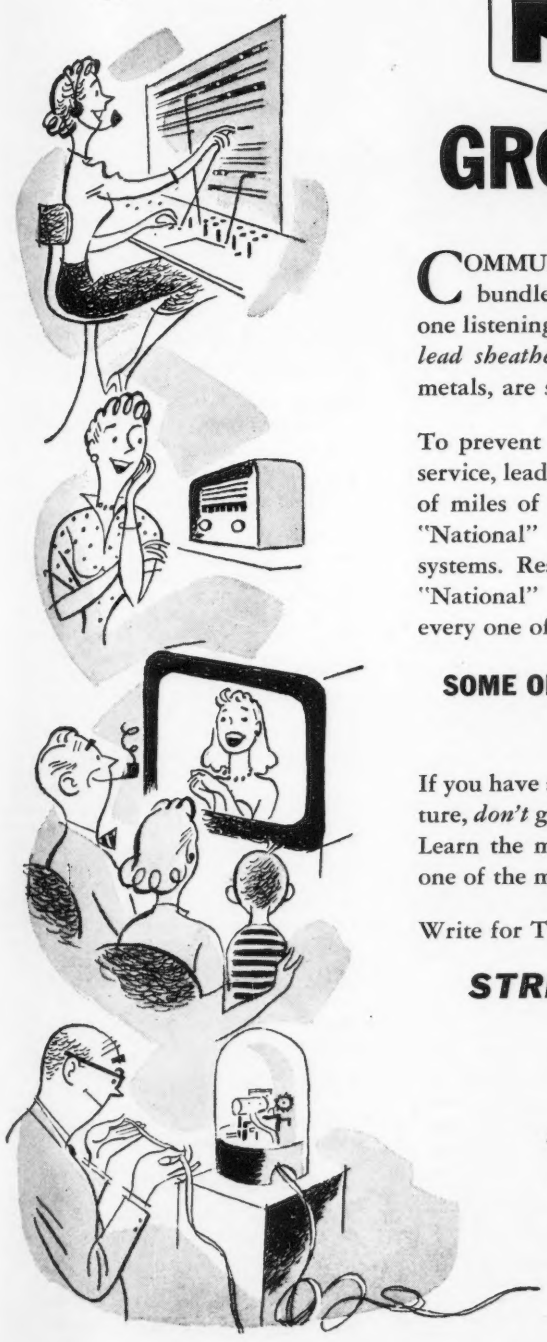

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MEN in the NEWS

George M. Hartley has been appointed manager of marketing for General Electric Company's Metallurgical Products Department, Detroit.

•

Bert R. Chenault, a graduate of Rensselaer Polytechnic Institute and Massachusetts Institute of Technology, formerly a design engineer with Air Preheater Corp., a process engineer with Magnolia Petroleum Corp. and sales engineer with Lummus Co. has been named manager of Badger Manufacturing Company's Houston office.

•

Leonard I. Meisel has been named Civilian Chief of the Testing Laboratories at Philadelphia Quartermaster Depot. He was Supervisor of the Plastics Branch, Naval Air Materials Center, Philadelphia.

•

John Thomas, formerly vice-president of engineering of Alco Products, Inc. died suddenly as result of a heart attack at Miami, Fla. August 31.

•

Clifford C. Furnas, Chancellor of University of Buffalo, and formerly director of Cornell Aeronautical Laboratory, Buffalo, N. Y. has been appointed assistant secretary of defense, research and development.

•

Robert Franklin Mehl, dean of graduate studies of Carnegie Institute of Technology has been designated to receive the Pittsburgh Award for 1956 by the Pittsburgh Section of the American Chemical Society.

•

J. C. de Graaf has been appointed sales manager of the Coatings Division of Furane Plastics, Inc., 4516 Brazil St., Los Angeles 29, Cal.

•

H. W. Schultze has joined Climax Molybdenum Company, 500 Fifth Ave., New York 36, N. Y. as assistant manager of chemical development.

•

Van H. Leichliter has been appointed president of American Steel and Wire Division, United States Steel Corp., Cleveland.

•

John D. McKinley has joined the Temperature Physics Section, National Bureau of Standards to undertake fundamental studies of reaction kinetics and related phenomena in gas-solid systems under extreme high temperature conditions.

•

Thomas G. Digges has been appointed assistant chief of the Metallurgy Division of the National Bureau of Standards. He has been a member of the division 36 years.

•

Charles R. St. Clair, Jr. has joined the Research and Advanced Development Division of Avco Manufacturing Corp., 20 S. Union St., Lawrence, Mass. as a senior scientist. He is a specialist in thermodynamics.

•

Eugene Sinnett has been named plant manager of the Corrulux Division, LOF Glass Fibers Co., Houston.

•

John A. Yourtee has been appointed technical superintendent of the American Viscose Corporation's Film Division plant at Marcus Hook. During the past year he has been coordinator of research and development activities at the Fredericksburg, Va., film plant.

•

David Stern has been named assistant manager of the American Potash and Chemical Corporation's research laboratory at Whittier, Cal.

•

G. A. Nelson, staff metallurgist at Shell Development Company, Berkeley, Cal. has received second place honors for his article "The Selection and Application of Stainless Steel in the Chemical Process Industries," in an annual competition conducted by American Society of Metals.

•

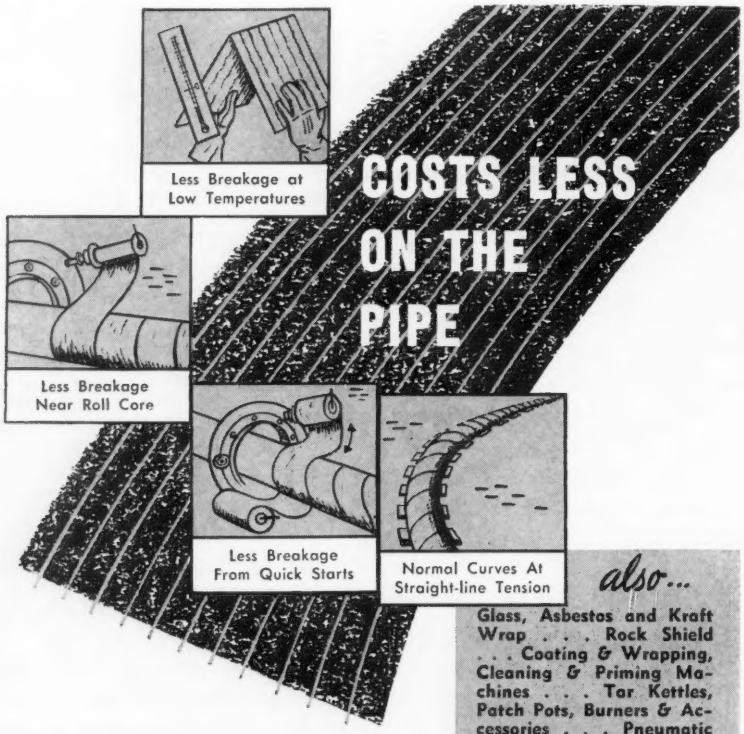
H. Thomas Hallowell, Jr., president of Standard Pressed Steel Company, Jenkintown, Pa. has been reelected president of the American Standards Association.

•

Robert F. Purcell has joined the nitroparaffins research staff of Commercial Solvents Corp. at its research laboratories in Terre Haute, Ind.

Hand Computer for Water Content of Gases Made

A simple hand computer for water content of gases has been developed by A. W. Diniak and E. R. Weaver of the National Bureau of Standards. The circular slide rule is described in an article by the inventors published in *J. Research NBS*, Vol. 56, Page 269 (1956) RP 2674.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CORROSION ABSTRACTS

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Vol. 12 December, 1956 No. 12

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2. TESTING

2.2 On Location Tests

2.2.2, 6.4.2, 4.2.4

Aluminium Roofing and Wall Paneling. (In German.) H. KENTZLER AND J. SCROEDER. *Aluminium*, **32**, No. 3, 147-150 (1956) March.

Service records of aluminum roofings in industrial areas of Germany and South America are discussed and it is explained how these experiences influenced the design and installation of aluminum roofs and walls at a major steel mill in Belo Horizonte (Brazil), comprising a total of 650,000 sq. ft. of corrugated aluminum sheet used. It is stated that 1) the fairly accurate knowledge of the weathering properties of aluminum sheet permits the prediction of its long service life in tropical climates, even if there is an industrial contamination of the air present; 2) the light weight of aluminum reduces transport costs and simplifies transport problems which are particularly significant in some tropical countries with an undeveloped transportation system; 3) the aluminum sheet used in the particular construction described, an aluminum-magnesium-silicon alloy, proved to be resistant to chemical and mechanical effects of a long journey at sea and of a prolonged storage at a Brazilian port. Results of corrosion tests and design details are presented.—ALL. 11597

2.2.5, 5.4.5, 8.10.2

Protective Coal Tar Coatings in Steel Plants. W. F. FAIR, JR. AND H. J. CIBULA. Koppers Co. Inc. *Iron Steel Engr.*, **33**, No. 2, 106-116; disc., 116-118 (1956) Feb.

Covers proper planning and design, surface preparation by pickling, flame cleaning, mechanical descaling and degreasing, selection of proper coating in accordance with its properties and the environment in which it is used and properties and applications of hot- and cold-applied coal tar enamels. For specific information on the use of these coatings in steel plant corrosion mitigation, report is made of inspections recently made of four major steel plants. Table is offered as guide for steel plant maintenance with coal tar coatings, listing such underground structures as water, effluent, gas and sewer lines and steel tanks and above ground structures including exterior pipelines, structural steel, piling, tanks, railroad ties and high-temperature surfaces. Illustrations, graphs, tables.—INCO. 11565

2.2.6, 6.2.1, 6.6.5, 7.2

Exposure Tests on Three Types of Pipe. M. J. SHELTON AND BERT C. WILKAS. *J. Am. Water Works Assoc.*, **47**, 1107-1123 (1955) November.

Soil corrosion tests of asphalt-mastic-coated steel, cast iron and asbestos-cement pipes. Diagrams, photographs, tables, graph. 2 references.—BTR. 11538

2.3 Laboratory Methods and Tests

2.3.2

Research on the Salt Mist Corrosion Test. Part III. Effect of Specimen Shape. G. BIANCHI AND U. GANDOLFI. *Metallurgia Italiana*, **47**, No. 12, 551-554 (1955) December.

Effect of position of specimen within test chamber, orientation of specimen, type of diffuser and composition of the salt solution on the corrosion of iron

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ATS—Associated Technical Services Abstracts, Associated Technical Services, P. O. Box 271, East Orange, N. J.
AWWA—Journal, American Water Works Association, Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.
BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.
BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.
BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.
CBEC—Centre Belge d'Etude de la Corrosion (CEBELCOR), 17 re des Drapiers, Brussels, Belgium.
CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.
EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.
EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.
GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.
IIM—Transactions, The Indian Institute of Metals, 23-B, Notaji Subhas Road, P. O. Box 737, Calcutta, India.
INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.
IP—Institute of Petroleum. 26 Portland Place, London W.#1, England.
JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chrome Nakameguro, Meguroku, Tokyo, Japan.
MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.
MI—Metallurgia Italiana, Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.
MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.
NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.
NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.
NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.
PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.
RAD—Reynolds Aluminum Digest, 2500 South Third Street, Louisville, Kentucky
RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.
RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.
SE—Stahl Und Eisen, Verlag Stahleisen, M. B. H., Dusseldorf, August-Thysen Str. 1. Postscheck Koln 4110, (22a) Dusseldorf, Germany.
TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.
UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.
ZDA—Zinc Development Association. 34 Berkeley Square, London W.1.

and zinc specimens. Use of salt solution containing sodium citrate is recommended. —BNF. 11719

2.3.2, 2.5

Salt Spray Testing. G. B. HOGABOOM, JR. *Metal Finishing* (Guidebook-Directory Ed.), **1956,** 496-499.

Typically used specifications for salt spray testing.—BTR. 11596

2.3.2, 2.5, 5.4.5, 5.5.3

Tentative Standard Method for the Assessment of the Rust Preventing Characteristics of Hard Film and Soft Film Temporary Corrosion Preventives. *J. Inst. Petroleum,* **42,** 50-54 (1956) Feb.

Report on method in which test panels are exposed to sulfur dioxide. Effectiveness and reproducibility studies. Tables. 3 references.—MR. 11600

2.3.2,5.8.1

Adapting the Static Water Drop Test to Research Methods. E. J. SCHWOEGLER AND L. U. BERMAN. *Lubrication Eng.,* **11,** 381-388 (1955) Nov.-Dec.

Presents in detail the method of preparing specimens so that a shorter test period of 48 hours can be used with duplicate samples. The test results are quite precise and accurate. More rapid tests are thus possible so that a large number of polar organic compounds may be evaluated in the search for optimum corrosion inhibition. Tables, photographs. 2 references.—BTR. 11528

2.3.2, 6.2.5, 2.3.4

Predicting Corrosion Resistance by Microscopic Examination. JOHN H. SCOTT. *Metal Progress,* **69,** 79-80 (1956) March.

Stainless steel plates which must pass a 240-hr. nitric acid corrosion test can be released while the test is in progress by use of a quick microscopic screening method. Micrographs.—MR. 11656

2.3.4

A Hydrogen Effusion Method for the Determination of Corrosion Rates in Aqueous Systems at Elevated Temperature and Pressure. M. C. BLOOM AND M. KRUFELD. U. S. Naval Research Laboratory, Report 4644, November 7, 1955, 15 pp.

In order to determine the resistance of metals to attack by aqueous media at high temperatures and pressures a new technique has been evolved: In a closed system the hydrogen resulting from the corrosion reaction diffuses through the walls of the metal and is collected and measured in a vacuum system. The rate of hydrogen evolution thus determined gives a direct measure of the rate of corrosion. Tests on steel with water at 316 C. Results are said to be reproducible and to line up with those obtained by an independent method.—BNF. 11704

3. CHARACTERISTIC CORROSION PHENOMENA

3.5 Physical and Mechanical Effects

3.5.9, 6.3.4, 6.2.5, 1.6

Development of Wrought and Cast Alloys for High Temperature Applications. R. R. MACFARLANE, R. S. DEFRIES, E. E. REYNOLDS AND W. E. DYRKACZ. Allegheny Ludlum Steel Corp. U. S. Wright Air Development Center, Tech. Rept. 55-23, April, 1955, 92 pp.

Developmental studies were conducted on wrought iron-base and both wrought and cast cobalt-base alloys for applications at high temperatures. A heat treatable, iron-base, austenitic alloy containing manganese and chromium was modified with boron to give excellent stress-rupture properties at 1200F. Oxidation resistance was greatly improved by small aluminum additions. A wrought cobalt-base alloy with good stress-rupture properties at 1600 and 1700F and improved oxidation resistance was developed. Composition levels giving optimum properties were determined for

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the cast cobalt-base alloys. Modifications involving boron were investigated in both wrought and cast cobalt-base alloys. (auth).—NSA. 11443

3.5.9, 6.3.15, 3.8.4

The Scaling of Titanium and Titanium-Base Alloys in Air. HAL W. MAYNOR, JR. AND ROY E. SWIFT. *Corrosion*, **12**, No. 6, 293t-304t (1956) June.

A preliminary study of the scaling characteristics in air of laboratory-produced titanium and titanium-base alloys, and commercially-produced titanium and titanium-base alloys was conducted at temperatures of 1200, 1400, 1600, and 1800F (650, 760, 870, and 980C) in the time range of approximately 4 to 300 hours. A total of 43 titanium-base alloys, one commercial grade of titanium (RS-70) and AISI Type 302 stainless steel were scaled at each of these temperatures; two additional alloys were employed at temperatures of 1200 and 1600F. Scales formed on a 4.02 percent aluminum-titanium alloy were studied in detail and a scaling mechanism was suggested; scales formed on a 4.03 percent chromium-titanium alloy and a 2.95 percent tungsten-titanium alloy were studied in less detail. Scaling tendencies of titanium-base alloys, relative to titanium and stainless steel were evaluated on the basis of weight gain with time. Isothermal transitions in scaling rate were observed for titanium and titanium-base alloys within the temperature range 1200-1600F. 11390

3.6 Electrochemical Effects

3.6.5, 3.8.2

Theoretical Electromotive Forces for Cells Containing a Single Solid or Molten Chloride Electrolyte. WALTER J. HAMER, MARJORIE S. MALMBERG AND BERNARD RUBIN. *J. Electrochem. Soc.*, **103**, 8-16 (1956) Jan.

From thermodynamic data, electromotive forces have been calculated for reversible galvanic cells of the type $M/MCl_n/Cl_2(z)$ where M is a metallic element in the solid, liquid, or gaseous state and MCl_n is the corresponding chloride in the solid or liquid state. Results are given for temperatures from 25 to 1500C. The chlorides are listed in a series and compared with the electromotive force series of the elements in aqueous solutions. Comparisons are given with results obtained from galvanic cells with fused chlorides or from measurements of decomposition voltage. (auth).—NSA. 11341

3.6.7, 3.6.2

Effect of Long Cell Action on Local Cells. ROBERT POPE. *Corrosion*, **12**, No. 4, 169t-170t (1956) April.

Long cell action can alleviate or aggravate corrosion caused by local cells depending on the location of the local cell. Corrosion conditions are aggravated in the anodic area of the long cell and more cathodic protection current is required to stop corrosion than would be required for the local cell alone. Corrosion conditions due to local cells are alleviated and conceivably could be eliminated by long cell action if the local cell were located in the cathodic area of the long cell. These effects are illustrated by polarization diagrams. 11123

3.6.8

Definition of Polarization and Overvoltage. K. NAGEL. Proc. 6th Meeting Internat. Cttee. Electrochem. Thermodynamics and Kinetics (Poitiers, 1954), 1955, 67.

For single electrodes, polarization = overvoltage of the potential-determining electrode reaction. For double electrodes, with double equilibrium in the currentless state, polarization = overvoltage of the electrode reaction α = overvoltage of the electrode reaction β. For double electrodes with mixed-galvanic potential, with no electrochemical equilibrium in the currentless state, polarization and overvoltages of both electrodic reactions α and β are different; e.g. corrosion electrodes.—MA. 11421

3.6.8

Hydrogen Overvoltage and Electrode Materials: A Theoretical Analysis. PAUL RUETSCHI AND PAUL DELAHAY. *J. Chem. Phys.*, **23**, No. 1, 195-199 (1955). Jan.

Ruetschi and Delahay show theoretically that the overvoltage for hydrogen evolution on various metals and for otherwise identical conditions of electrolysis is essentially a linear function of the heat of adsorption of atomic hydrogen on the electrode. They have assumed that the effect of backward electrode reaction can be neglected and that the current is controlled by the discharge of hydrogen ions; they show that this is so for overvoltages larger than 0.1-0.15 V. Details are given of the relationship between overvoltage and heat of adsorption for silver, beryllium, cadmium, chromium, copper, tellurium, gallium, mercury, indium, nickel, lead and thallium. Potential energy curves are constructed for the initial and final states, using available spectroscopic data. Use is made of a kinetic equation for hydrogen overvoltage and the heats of adsorption

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of atomic hydrogen are found by assuming the additivity of the M-M and H-H bond energies. The calculated heats of adsorption are listed for 25 metals. It is also shown that there is no correlation between hydrogen overvoltage for various metals and the electronic work-function of these metals. 40 references.—MA. 11507

3.6.8, 3.8.2, 6.5

Polarization Studies of Copper, Nickel, Titanium, and Some Copper and Nickel Alloys in Three Percent Sodium Chloride. H. B. BOMBERGER, F. H. BECK AND M. G. FONTANA. *J. Electrochemical Society*, **102**, 53-58 (1955) Feb.

Relationships between potential, time, current, corrosion rate and solution velocity. Diagram, tables, graphs. 11 references. —MR. 11300

3.7 Metallurgical Effects

3.7.3, 6.4.2

Stabilising Heat Treatments for Aluminium-5% Magnesium Alloys to Counter the Effect of Heating at Moderate Temperatures. (In French.) A. GUILHAUDIS. *Rev. Aluminium*, **32**, Nos. 223, 224, 717-725, 795-801 (1955) July-August, September.

Low temperature heat treatments (70-200C) can make aluminum-magnesium alloys (up to 5 percent magnesium) susceptible to intercrystalline corrosion. Stress corrosion tests were carried out in 3 percent sodium chloride/1 percent hydrochloric acid and artificial sea water after low temperature heat treatment of specimens sometimes followed by different stabilizing treatments. Effect of different stabilizing heat treatments, rate of cooling, etc., on the stress corrosion and tensile properties (at intervals during corrosion tests). 9 references.—BNF. 11458

3.7.3, 6.4.2

The Effect of Cold Work and Heat Treatment on the Rate of Dissolution of Pure and of Impure Aluminum in Acids tnd Bases. M. E. STRAUMANIS AND Y. N. WANG. *Corrosion*, **12**, No. 4, 177t-182t (1956) April.

The rate of dissolution of a 99.99 percent pure, one way cold rolled aluminum sheet as received was determined in 1 N hydrofluoric acid and compared with the rates obtained with a 400 to 575C recrystallized aluminum specimen of the same quality. No significant difference in rates could be detected. There also was no difference in the dissolution rates of surfaces cut under different angles with repect to the direction of cold rolling.

The same dissolution behavior was observed with 99.998 percent pure aluminum in 0.5 N barium hydroxide solutions; there was no difference in rates of the cold rolled and recrystallized samples, except for cold hammered samples, which showed higher rates. Differential heat treatment of aluminum alloys (with 1 and 2 percent copper), however, produced different rates; the samples heat treated at 200C exhibited lower rates of dissolution.

The conclusion reached is that cold work itself evidently does not influence the rates of dissolution of aluminum in hydrofluoric acid and in barium hydroxide solutions. However, the effect of cold work may be felt indirectly by creation of cracks and fissures in the metal, which increase the rate of dissolution. Changes in the constitution of the aluminum due to the heat treatment if the metal is impure, may also influence the rates of dissolution. 11241

3.7.3, 6.4.2, 8.9.5

An Analysis of the Behavior of Rivetted Joints in Aluminium Alloy Ships' Plating. A. R. FLINT. *Trans. North East Coast Inst. Engrs. and Shipbuilders*, **72**, No. 2, 83-122 (1955) Dec.

Elastic behavior, strength and watertightness of rivetted plating in aluminum alloy N6 (5% magnesium). Steel rivets were found to be unsuitable for most joints; N6 rivets are preferred. Design recommendations are made.—BNF. 11400

3.7.3, 7.7, 6.4.2

Bolted Connections in Aluminium Bus-Bars. J. C. BAILEY. *Engineer*, **199**, No. 5178, 551-554 (1955).

A full review is given of laboratory experiments on mechanical jointing techniques and observations and experience with actual bus-bar installations over the past thirty years. Recommendations are made for making bolted connections, so as to yield joints of low resistance which will withstand the effects of temperature changes and corrosive action over long periods.—MA. 11240

3.8 Miscellaneous Principles

3.8.3, 4.7

Kinetics of the Passivation of Mercury. L. GIERST AND L. BOURGEOIS. Proc. 6th Meeting Internat. Cttee. Electrochem. Thermodynamics and Kinetics (Poitiers, 1954), 1955, 273-279.

A study has been made of the anodic behavior of mercury and conclusions drawn from the variation of the time to onset of rapid polarization with the current density and with the nature and concentration of the anion. With no stirring, the duration of the transition step may be determined by the modes of transport of anion to the electrode (diffusion, migration, convection). A passive state may be attained when the concentrations of the anion and cation at the electrode exceed the solubility product of the salt; the time of passivation is still determined by the kinetics of transport. Sometimes the mechanism of growth of the deposit becomes the controlling factor. The general laws enunciated may cease to hold if the transition time exceeds several seconds. In sodium hydroxide and potassium iodide solutions, the behavior observed can be interpreted only in the light of more complex mechanisms.—MA. 11401

3.8.3, 6.2.5

Passivation of Chromium Steels in 6.5% Nitric Acid, Sulphuric Acid Containing Copper Sulphate Solution and Tap Water. C. CARIUS. *Arch. Eisenhuttenw.*, **26**, 769-776 (1955) Dec.

Investigation of corrosion behavior of ferritic chromium steels (2-27% chromium) in 6.5% nitric acid. Potentials in acidified copper sulfate solution, tap water and nitric acid were determined. Passivation processes showing characteristic behavior of ferritic and martensitic chromium steels are described. Determination of minimum chromium content required for passivation was made.—INCO. 11388

3.8.4, 2.3.9

Investigations of Metal Surfaces, Using (the) Exo-Electron and Photo-Electron (Effects). J. KRAMER. *Metalloberflache*, Sec. A, **9**, Nos. 1, 2, 1-6, 28-31 (1955).

A survey of recent work—mainly by Kramer—on 1) the nature and detection of the emission of electrons—exo-electrons and photo-electrons—from metal surfaces and 2) the use and applications of these phenomena—which appear to be intimately connected with changes or reactions on and in the emitting surface of the metal—as a method of investigating the characteristics of metal surfaces, e.g. the structure of naturally and artificially produced oxide films on aluminum. 13 references.—MA. 11423

3.8.4, 3.2.3

Electron-Microscope Studies of Metal-Oxide Layers. (In German.) GERHARD PFEFFERKORN. *Z. Metallkunde*, **46**, No. 3, 204-207 (1955) March.

Electron-microscope studies of oxidized metal surfaces show that in many cases needles and lamellae of oxide protrude vertically from the main oxide surface. Continuing growth of these protuberances occurs at the apex and not at the base and this, in conjunction with the specific properties of the surfaces of such needles and lamellae, leads to the conclusion that growth takes place by surface diffusion. The thickness and the length of needles on copper and iron are dependent on time and temperature of oxidation. The increase in the surface area of the oxide layer resulting from protuberances can be related to chemisorption, electrical-conductivity and catalytic-activity phenomena of such surfaces. Electron micrographs of oxidized surfaces of phosphor-bronze, tantalum, zinc, iron, nickel, molybdenum and copper produced by heating for various times at various temperatures are reproduced.—MA. 11493

3.8.4, 6.4.2, 3.4.8

A Radiochemical Tracer Investigation of the Role of Mercury in the Corrosion of Aluminum. R. C. PLUMB, M. H. BROWN AND J. E. LEWIS. *Corrosion*, **12**, No. 6, 277t-285t (1956) June.

A radioactive tracer investigation of the role of mercury in the corrosion of aluminum is described. Radioactive tracer techniques have permitted this study to be carried out more precisely than possible by standard analytical techniques, because they permitted accurate quantitative measurements of mercury pickup and revealed the distribution of mercury on exposed specimens. Particular attention has been given to the mechanism by which aluminum corrodes in a solution of mercuric salt. A process by which mercury makes the initial attack on aluminum, the manner in which further pickup takes place and the relationship between the mercury pickup and the resulting corrosion have been deduced. Several results of practical consequence are described. Included is a technique for removing mercury contamination from aluminum. 11385

5. PREVENTIVE MEASURES

5.3 Metallic Coatings

5.3.2, 6.2.2

Characteristics of Copper-Infiltrated Porous Iron. J. E. ELLIOTT. *Metallurgia*, **52**, No. 313, 226-234 (1955) Nov.

Basic principles of infiltration applied to iron-copper alloys; copper-iron equilibrium diagram (in the region 0-10% and 86-100% iron); infiltration of iron using pure copper, copper-2.4% iron (molten), copper-iron powder and copper-manganese-iron; effect of skeleton characteristics, composition, time of infiltration, heat-treatment cycles, etc., on mechanical properties of iron-copper alloys. Photomicrographs are given.—BNF. 11472

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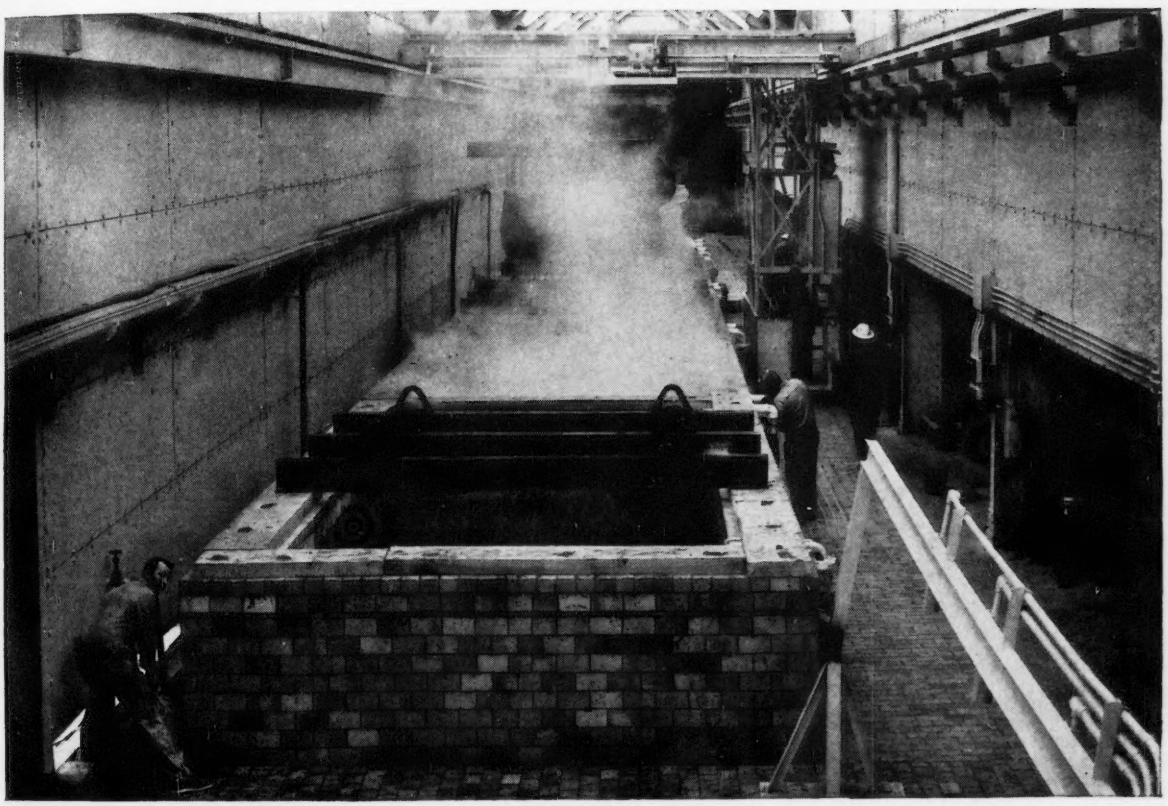

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5.3.2
Cathode Electronic Structure and Metal-Ion Deposition. T. P. HOAR AND A. I. BUCKLOW. *Chemistry & Industry*, No. 34, 1061 (1955) August 20.

It is well known that tungsten cannot be electrodeposited by itself, though deposition simultaneously with iron, nickel or cobalt is readily possible. Authors suggest that this is because tungsten ions, like hydrogen ions, are much more easily deposited on the alloy surface than on tungsten because of a more favorable electronic structure of the alloy.—BNF. 10940

5.3.2
Bimetals. W. RIFNACKER. *Z. Metallkunde*, **46**, 429-434 (1955) June.

Bimetals are defined as clad metals, in which the properties of the components are each utilized to give desired final effect. Bimetals as used for electrical contacts are discussed. Detailed treatment of thermal bimetals and the common combinations used: nickel-manganese-iron (mainly 20-6-74) with iron and nickel-iron alloys (36, 42, or 46% nickel) is given. Thermal expansion characteristics of the components and the composite bimetals are discussed. Mention is made of other materials (nickel-cobalt-iron alloys, tungsten, molybdenum) of low thermal expansion and of possible application as thermal bimetals. Calculation of deflection of bimetals, and properties and applications are included.—INCO. 10947

5.3.2
Properties and Uses of Heavy Nickel Deposits. J. W. OSWALD. *Electroplating & Metal Finishing*, **8**, No. 11, 379-383 (1955) Nov.

Review of nickel plating covers plating solutions in general, adhesion, hardness, effects of heat, corrosion resistance, fretting corrosion, finishing of deposited nickel and comparison of nickel deposition with hard chromium plating, welding and sprayed metals. Tables list typical plating baths and properties of electrodeposited nickel and chromium. Test specimen used in adhesion test is shown. Graphs show effect of heat on hardness (200-800C) and comparison of fatigue limits of plain mild steel and nickel deposited specimens under corrosive conditions. Industrial applications discussed include plating of steel or cast iron hydraulic rams, general salvage of worn parts and numerous corrosion resisting uses.—INCO. 10925

5.3.2
Diffused Nickel Cadmium as a Corrosion Preventive Plate for Jet Engine Parts. R. W. MOELLER AND W. A. SNELL. Paper before Am. Electroplaters' Soc., 42nd Ann. Conv., Cleveland, 1955. *Proc. Am. Electroplaters' Soc.*, **1955**, 189-192; Plating, **42**, No. 12, 1537-1540 (1955) Dec.

Corrosion resistance requirements on low alloy steel jet engine parts operating at temperatures up to 1000F are met satisfactorily by diffused electroplated coating of 0.0002-0.0004-inch nickel plus 0.0001-0.0002-inch cadmium. Continuous production of complex nickel-cadmium plated parts is accomplished through use of conforming nickel anodes and rigid processing control to regulate plate thickness and prevent presence of free cadmium. Production plating to proposed AMS 2416 is discussed. Illustrations show plating set-up. Salt-spray corrosion test data are given.—INCO. 10911

5.3.2
The Selection of Electroplated Coatings. Am. Soc. Metals Ctte, on Electroplated Coatings. *Metal Progress*, **68**, No. 2-A, 97-105 (1955) August 15.

Supplements an article on pp. 716-720 of the 1948 ASM Metals Handbook. A general account without details of baths and conditions of plating. Protective and protective-decorative coatings (cadmium, zinc, copper-nickel-chromium, nickel-copper-nickel-chromium, nickel-chromium, substitutes for copper-nickel-chromium, nickel, copper and brass), special purpose electroplates. Considerable discussion of applications.—BNF. 10906

5.3.2
What You Should Know About Clad Steels. H. F. PETERS. Lukens Steel Co. *Chem. Eng.*, **62**, No. 10, 234, 236, 238, 240, 242 (1955) Oct.

Discusses the advantages, properties and characteristics, forms and sizes, thermal conductivity and fabrication including heat treating, shearing, punching, forming, machining, flame cutting, arc welding, finishing and stress relieving, of steels clad with nickel, stainless steel, Inconel, Monel or copper. Application of clad steels in construction of tanks, pressure vessels and other equipment in industrial processes is considered. Table gives maximum hot working and annealing temperatures. Diagrams indicate standard welding procedure. Illustrations.—INCO. 10897

5.3.2
Growth Spirals in Electrodeposited Copper. H. J. PICK. *Nature*, **176**, No. 4484, 693 (1955) October 8.

Recent examination of surface of electrodeposited copper has led to the identification of spirals. Copper was deposited at 10 m.amp./cm. on a polycrystalline sheet of copper (cold-rolled and annealed) with grains so orientated that (100) planes were parallel to surface and (001) directions parallel to rolling direction. Types of spirals observed were those deposited from adqeous N/2 cupric sulfate plus N/2 sulfuric acid in which rate of growth varied with crystallographic direction and those deposited from neutral aqueous N/2 cupric sulfate in which growth was insensitive to crystallographic direction.—INCO. 10957

5.3.2
Recent Developments in Chromium Diffusion. Part III. Application and Properties of Chromised Metals. R. L. SAMUEL, N. A. LOCKINGTON AND H. DORNER. *Metal Treatment*, **22**, No. 119, 336-340 (1955) Aug.

Corrosion-resistance (natural conditions and special solutions), heat- and wear-resistance; applications utilizing these properties. 9 references.—BNF. 10980

5.8 Inhibitors and Passivators

5.8.3
The Mechanism of the Inhibition of Corrosion by the Pertechnetate Ion. Part II. The Reversibility of the Inhibiting Mechanism. G. H. CARTLEDGE. *J. Phys. Chem.*, **60**, 28-32 (1956) January.

An attempt has been made to determine the extent to which the process responsible for the inhibition of corrosion by the pertechnetate ion is reversible. It has been found that the disturbance of inhibition by added electrolytes involves a specific action and not merely an increase in electrical conductivity of the solution phase. The electrode potential of electrolytic iron was measured both in potassium pertechnetate and in mixtures of this with other electrolytes. The potential was found to respond quickly to changes in the composition of the solution in a manner that clearly represented kinetic influences at the interface. It is concluded that the potential and the inhibition alike depend upon a liable state at the interface that is quickly responsive to changes in the composition of the solution. (auth).—NSA. 11335

5.8.3, 3.8.4
Wettability of Solid Surfaces and the Inhibition of Corrosion. (In French.) G. P. BOLOGNESI AND L. FELLONI. *Corrosion et Anti-Corrosion*, **3**, No. 4, 167-171 (1955) July-August.

Investigation of effect of various wetting agents on the corrosion rate of aluminum in sodium hydroxide and hydrochloric acid, zinc and iron in hydrochloric acid: among agents tested were mercuric chloride, *o*-tolylthiourea, *o*-tolyl isothiocyanate *o*-toluidine, bone glue and triethanolamine. Six references. Results with mercuric chloride are of theoretical interest: for maximum corrosion rate there appears to be an optimum mercuric chloride/sodium hydroxide relationship.—BNF. 11383

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.3, 6.2.4
How to Avoid Brittle Failures in Steel. G. H. ENZIAN. Jones & Laughlin Steel Corp. *Materials & Methods*, **42**, No. 5, 116-118 (1955) November.

Brittle failures at —20 to 650F in carbon and low-alloy steels occur in form of notch brittleness and low ductility resulting from strain aging. These failures can be avoided by increasing the degree of deoxidation, alloying with nickel, increasing ratio of manganese to carbon in steel-making practice, decreasing grain size, removing effects of cold work or strain aging and by careful design, proper heat treatment and care in fabrication. Graphs.—INCO. 11484

6.2.5, 3.8.3
Passivation Rate and Potential of Alloy Kh28T3 (Chrome-Titanium Steel) in Sulfuric Acid Solutions. E. I. LITVINOVA. *J. Applied Chem., USSR* (Zhur. Priklad. Khim.), **28**, No. 12, 1285-1290 (1955) Dec.

Treated in 4 and 5 N sulfuric acid, alloy goes into stable, passive state, with an increase in potential. Influence of oxygen and condition of surface is shown. Five figures, 17 references.—ATS. Translation available: Associated Technical Services, P. O. Box 271, East Orange, New Jersey. 11424

6.2.5, 3.8.4, 3.2.3
Oxide Films on Stainless Steels. THOR N. RHODIN. *Corrosion*, **12**, No. 3, 123t-135t (1956) March.

Oxide films on stainless steels have been classified into three types according to film thickness, film structure, film composition and influence of the film on resistance to corrosion.

Compositional properties of oxide films isolated from surfaces of stainless steels were studied using specially developed microanalytical techniques. Properties of passive films on stainless steel were evaluated and the effects of alloy composition and

surface treatment on other types of films on Types 304, 316 and 347 stainless steels were studied.

The influence of corrosion in various media was correlated with film compositional properties. Composition of films after immersion in acids was found to be related to film composition prior to immersion. The effect of immersion depended on the nature and intensity of corrosion and was reflected most sensitively by the iron and silicon contents of the films.

The conclusion was made that film properties indicate strongly the capacity of austenitic stainless alloys to develop corrosion-resistant surfaces in certain environments. 11153

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.15, 3.5.9

Tensile Properties of Some Titanium Alpha Solid Solutions up to 600C. J. W. SUITER. *J. Inst. Metals*, **83**, No. 10, 460-464 (1955) June.

Determinations of U.T.S. and elongation for titanium and titanium binary alloys containing nitrogen, oxygen, carbon, aluminum, tin or zirconium. Strengths of all alloys decreased rapidly with rise in temperature to 300C but remained approximately constant between 350 and 500C. Results discussed in terms of interstitial "atmospheres" around dislocations and possible mechanism for improved high temperature strength.—BNF. 11069

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6.3.15, 3.5.9, 3.8.4

A Further Study of the Oxidation of Titanium and Its Alloys at Elevated Temperatures. A. E. JENKINS. *J. Inst. Metals*, **84**, No. 1, 1-9 (1955) Sept.

Cf. *ibid.*, **82**, 213 (1953-1954). Using a sensitive volumetric technique, a close study has been made of the oxidation of pure titanium and certain binary titanium alloys for the first eight-hour period of reaction. Investigations were completed in the temperature range 650-950C and at oxygen pressures ranging from 700 to 40 mm. Hg. The alloys chosen contained ~5 at.—% tin, zirconium, iron, aluminum or tungsten. The initial period in the oxidation of the pure metal has been found to conform to a parabolic law. The period for which this relationship is valid is governed by the formation of an initial coherent scale layer on the specimen to what appears to be a constant thickness; thus, at higher temperatures, the parabolic growth period decreases in duration. The initial period is often terminated by an abrupt change in reaction rate, after which the reaction conforms to an approximately linear rate. Further abrupt changes occur at irregular intervals, resulting in a slow increase in the overall rate of reaction. Although variations in the oxygen pressure and the physical state of the specimen had no noticeable influence on the general behavior, the effects produced by alloying proved to be significant. Aluminum and tungsten decreased the oxidation rate of titanium at 900C after a short initial period had passed, whereas tin produced a catastrophic decline in the oxidation-resistance of the metal. (auth). —MA. 10933

6.3.15, 3.7.2

Studies of the Corrosion Resistance of Titanium Alloys. Part I. Corrosion Resistance of Titanium-Aluminum and Titanium-Nickel Alloys. S. YOSHIDA, S. OKAMOTO AND T. ARAKI. *J. Mechanical Laboratory* (Japan), **9**, No. 2, 51-60 (1955) Mar.

The corrosion rates for titanium-aluminum (1-5%) and titanium-nickel (1-10%) alloys were determined in various test solutions at ordinary and boiling temperatures. Alloys were arc melted in argon atmosphere and hot rolled and cold rolled to 1 mm thick plates. The corrosion resistance of titanium is much improved by the addition of aluminum and nickel in hydrochloric acid (10%), acetic acid (99%), formic acid (25%), ammonia water (5%), potassium hydroxide (5%), ferric chloride (30%) and aluminum chloride (saturated) solutions. Titanium resistance is somewhat improved by addition of aluminum in nitric acid solutions and by addition of nickel in oxalic acid (saturated) solution. Resistance of titanium is not influenced by addition of aluminum and nickel in aqua regia and sodium chloride (3%) solution. Addition of aluminum and nickel in sulfuric and hydrochloric acid (20%) solution and addition of nickel in nitric acid solutions decreased resistance to corrosion.—JSPS. 11057

6.3.18, 1.6

(Rare and Unusual Metals. Annual Report No. 3 for the Period May 15, 1953 to June 14, 1954.) Exploration of Vanadium-Base Alloys. ALBERT S. YAMAMOTO AND WILLIAM ROSTOKER. Armour Research Foundation. U. S. Wright Air Development Center, Tech. Rept. 52-145 (Pt. 3), January, 1955, 75 pp.

The oxidation study on vanadium alloys has been further pursued and the conclusion has been reached that satisfactory oxidation resistance at elevated temperature of vanadium-base alloys cannot be rendered by alloying alone but possibly by electroplating. Major efforts have been directed toward evaluating the elevated temperature tensile and stress-rupture strengths of the alloys under development. Carbon additions have proven beneficial as far as the forgeability is concerned. In certain cases superior tensile ductilities are observed while no effect in stress-rupture behavior results. The current availability of less expensive vanadium-aluminum alloy produced by the alumino-thermic reduction process has promoted a feasibility study of its use. It is found that the alloys made of this are as competitive in mechanical properties as the equivalent alloys based on the very expensive calcium-reduced vanadium metal. A range of alloy compositions containing additions of titanium and aluminum have shown stress-rupture behavior which is as good or marginally better than the best titanium-base alloys. (auth.) —NSA. 11051

6.3.19, 4.2.7

Behaviour of Pure Zinc Alloys in the Tropics. (In German.) W. WOLF. *Metall*, **9**, No. 15/16, 655-658 (1955) August.

The die-casting alloy known in Germany as ZnAl4 (Z400; 4 aluminum, 0.4 copper, 0.03 magnesium) is preferred for tropical use. Intercrystalline corrosion need not be feared if composition and impurities are controlled according to German specification DIN 1743. Dimen-

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Number 7 of a series

F. P. Filer
Project Leader

In this Corrosion Report, we would like to explore the functions of primers and the contribution which they can make toward the success of protective coating systems. While every step in a protective coating system is important, from precoating survey to finished coating, one of the more important is priming.

* * *

Basically, primers have one specific function: to bond intermediate and finish coats to the metal surface. To perform this function properly, it is vitally important that the primer be compatible with the intermediate and finish coats.

* * *

While priming is used with most protective coatings—with the exception of certain proprietary coal-tar coatings—no primer can compensate for incomplete surface preparation. The Steel Structures Painting Manual states specifically, "Any primer sold on the basis that it eliminates the preparation of the surface should be viewed with extreme caution." Rust, dirt, grease, and loose scale should *always* be removed before priming. In some cases, primers are applied over tight mill scale in the shop. Good practice would dictate removal of scale before priming to obtain a long-lived coating system.

We have often been asked whether shop primers (applied by the metal fabricator) should be used. One disadvantage is that they sometimes become badly scratched in transit and require considerable touch-up on the job site. Other drawbacks are that shop primers may not provide protection for a sufficiently long period, and may be applied without regard to their compatibility with the field coating specified. Also, shop primers may cover up inadequate surface preparation jobs.

The following points should be considered before specifying shop primers: (1) corrosivity at the job site; (2) estimated time between shop priming and field coating; (3) compatibility with the coating.

* * *

The terms "wash primer" and "primer" should not be confused. A wash primer is not a true primer but an integral part of surface preparation. It does not take the place of a primer when priming is required. Sometimes, wash primers are specified for short-term protection before application of self-priming, cold-applied coal-tar coatings.

* * *

From an application standpoint, there are three characteristics of primers that are of importance: wetting ability, consistency, and drying time. Properly selected and applied, primers should provide a uniform, tightly-bonded film to which the coating system will adhere tenaciously.

* * *

Your comments on these Reports will be appreciated. If there are any specific questions which you have relating to corrosion control, write Koppers Company, Inc., 1450 Koppers Building, Dept. 10JM, Pittsburgh 19, Pa. District Offices: Boston, Chicago, Los Angeles, New York, Pittsburgh and Woodward (Birmingham) Ala. In Canada: Koppers Products, Ltd., Toronto, Ontario, and Edmonton, Alberta.

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sional stability is assured by a heat treatment; otherwise a shrinkage of 0.4% maximum occurs. Surface protection against atmospheric moisture is necessary.—BNF. 11064

6.3.19, 4.3.2, 3.8.4

Selective Corrosion of Zinc. (In Russian.) I. I. ZABOLOTNYI, V. P. KOVTUN AND B. M. KRIMERMAN. *J. Applied Chem.*, USSR (Zhurnal Prikladnoi Khimii), **28**, No. 6, 655-659 (1955) June.

Corrosion data in sulfuric, hydrochloric, nitric acids and mixtures of hydrochloric + nitric acid at room temperature are reported. 5 figures, 6 references.—ATS. Translation available: Assoc. Tech. Services, P. O. Box 271, East Orange, New Jersey. 11050

POSITIONS WANTED and AVAILABLE

- Active and Junior NACE members and Companies seeking employees may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.
- Advertisements to other specifications will be charged for at $10 a column inch.

Positions Available

Corrosion Engineer—Major oil company has opening in Venezuela for corrosion engineer. Experienced application cathodic protection, pipe coatings, etc. Age to 40. Mail resume to P. O. Box 35, Bowling Green Station, New York 4, N. Y.

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COKE BREEZE

Backfill for Anodes

Ideally suited for use with anodes. Has a high carbon content and comes in sizes of ⅛-inch x 0 to ⅝ x ⅞-inch. In bulk or sacks. Prices on other sizes on request.

National Carbon Anodes
Magnesium Anodes
Good-All Rectifiers

Wholesale Coke Company

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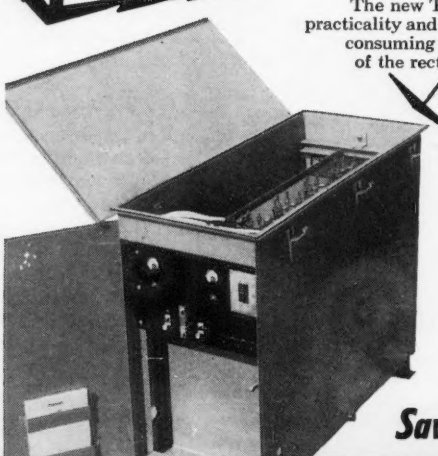
MT. OLIVE, ALABAMA

New TOGGLE LATCH makes it a SNAP to open

OIL IMMERSED

Good-ALL CATHODIC PROTECTION RECTIFIERS



The new TL appeals to engineers because of its practicality and convenience. TL eliminates the time-consuming job of removing bolts from four sides of the rectifier, then lifting off a heavy top. To change output taps, just snap open the toggle latches (TL) and swing open the hinged top. It's as quick and easy as that. Good-All's new top arrangement makes the rectifier so easily accessible that engineers no longer find it necessary to specify external adjusting taps, thus saving considerable in extra cost. The top is completely weatherproof. There are no bolt holes, and a wide Neoprene gasket prevents dust from entering. Oil immersed units can also be furnished with explosion-proof switches, meters and fittings.

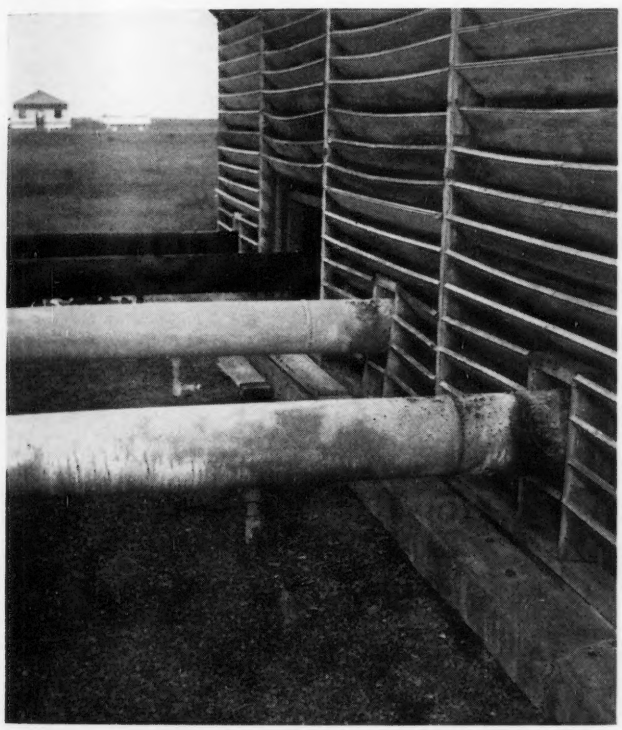
Saves Time–Saves Money

21-M

GOOD-ALL ELECTRIC MFG. CO.

Electrical-Mechanical Div. OGALLALA, NEBRASKA

TWO-YEAR TEST PROVES "SCOTCHRAP" STOPS CORROSION

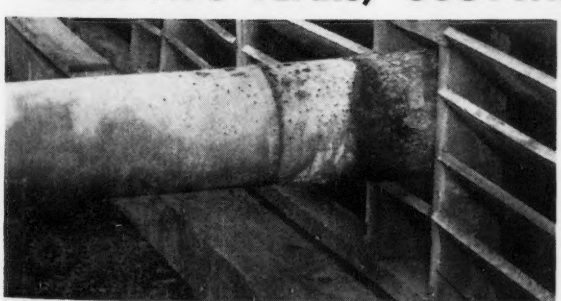


How the test was made:

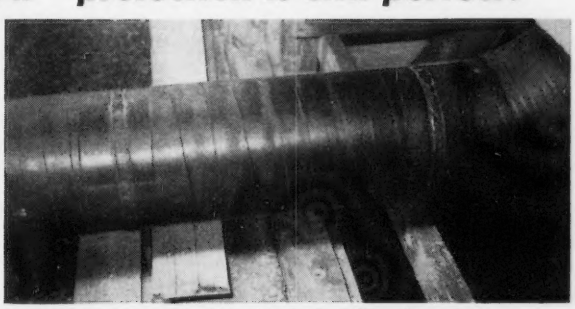
"SCOTCHRAP" Brand Pipe Insulation really got an "acid test" in this installation. In the photo at left, the two far pipes feeding into a compressor station cooling tower were covered with "SCOTCHRAP" Pipe Insulation . . . the near pipes were protected with the best available paint. From March 23, 1954, when the "SCOTCHRAP" and paint applications were made, until April 4, 1956, when the insulation was removed and these photos taken, these pipes were subjected to spray of the acid and chlorine bearing water from the tower, as well as sunlight and weathering. Average operating temperature of the pipes was 150° F.

• • • • •

After TWO YEARS, "SCOTCHRAP" protection is still perfect!



UNPROTECTED PIPE shows the effects of the corrosive action of the water splash from the cooling tower. Severe scaling and pitting are evidenced, and these pipes must be replaced. Water was highly corrosive due to acids and chemicals used for scale and algae control.



"SCOTCHRAP" COVERED PIPE looked like this when unwrapped — so perfectly intact you can still see the imprint of the "SCOTCHRAP" Adhesive on the prime coat. When prime coat was scraped away, pipe metal underneath was shiny, sound, good as new!

● If you have corrosion problems, why not let us send you the complete story on "SCOTCHRAP" — the tough, pressure-sensitive polyvinyl-chloride tape that gives complete corrosion protection. Just write on your letterhead to 3M Co., St. Paul 6, Minn., Dept. BQ-126.

Reg. U.S. Pat. Off.

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PIPE INSULATION

The term "SCOTCHRAP" is a registered trademark of Minnesota Mining and Manufacturing Co., St. Paul 6, Minn. Export Sales Office: 99 Park Avenue, New York 16, N. Y. In Canada: P.O. Box 757, London, Ontario.

3M

6.3.11, 3.8.4

Influence of Alternating Current on the Anodic Corrosion of Platinum. A. Rius, J. Llopis and F. Colom. *Anales Real. Soc. Espan. Fis. y Quim*, B, **51**, 11-20 (1955); *Chem. Absts.*, **49**, 8006 (1955) June 25.

Study of influence of superposed alternating current, of variable frequency and intensity, on anodic corrosion of platinum, using dilute sulfuric and hydrochloric acids.—INCO. 10632

6.3.10, 5.3.2

The Role of Nickel in the Fight Against Corrosion. M. Ballay. Paper before Corrosion Group, Soc. de Chimie Industrielle, April 7, 1955. *Corrosion et Anti-Corrosion*, **3**, 213-221 (1955) Sept.-Oct.

Review of applications and corrosion-resisting properties of pure nickel, nickel-clad materials, nickel electrodeposits, Monel, cupro-nickels, nickel-containing bronzes, Inconel, 18/8 stainless, nickel-chromium-iron alloys, 19/9 DL, S. 588 and 590, G 18 B, Nimonic 75 and 80, Inconel X, Hastelloy alloys, nickel-containing cast irons, Ni-Resist.—INCO. 10694

6.3.10

The Heat-Treatment, Inspection and Testing of Wrought Nickel and Nickel Alloys. W. Betteridge and T. E. Cound. *J. Inst. Metals*, **83**, No. 6, 262-270 (1955) Feb.

Checking composition (including rapid spot tests); production of different forms (rolled or extruded, bars, forgings, sheet and strip, wire, tube); annealing sheet, strip and wire; precipitation hardening; inspection for internal and surface defects; various special process tests; physical and mechanical testing (magnetic, controlled-expansion and electrical-resistance alloys; life testing and creep); packing and dispatch.—BNF. 9935

6.3.10, 6.3.4

Nickel Including High-Nickel Alloys. H. O. Teeple. *Ind. & Eng. Chem.*, **47**, No. 9, Pt. 2, 1990-2006 (1955) September.

Current annual review of published references relating to nickel and nickel alloys. Alloys containing 40% or more of nickel or substantial quantities of cobalt are considered. Developments on sources of nickel and cobalt supply; developments of new alloys or improvements in present ones and studies of their properties; developments in fabrication and working of these alloys; and development applications of these alloys with particular reference to high temperature and chemical and process industries applications are reviewed. 266 references.—INCO. 10993

6.3.11, 7.7

Silver as a Material in Electrotechnics. (In German.) A. Keil and C. L. Meyer. *Schweiz. Archiv. angew. Wiss. u. Tech.*, **21**, No. 8, 264-270 (1955) Aug.

After tables showing properties of silver and uses of the metal and its alloys in numerous electrochemical applications, discusses application of fine silver and sintered silver products (pseudo-alloys) for contacts for circuit breakers; electrodeposited silver coatings; silver coatings on non-conductors; silver solders. 15 references.—BNF. 10935

6.3 18, 3.8.2

Electrochemical Behavior of Vanadium. (In French.) E. Deltombe, N. de Zoubov and M. Pourbaix. Cebelcor Rapport Technique No. 29, January, 1956, 26 pp. Available from: Centre Belge d'Etude de la Corrosion, 21 rue des Drapiers, Bruxelles.

The paper consists of a critical examination of the characteristics of the system V-H_2O at 25C. Equilibrium diagrams are given. Thirty-eight references and eight figures are included. This is an extensive mathematical investigation of the system. 11340

6.3.20

Evaluation of a Modified Zircaloy-2 Ingot F-1071 Melted at WAPD. J. G. Goodwin. Westinghouse Electric Corp. U. S. Atomic Energy Comm. Pubn. AECD-3688, April 14, 1954 (Declassified with deletion October 24, 1955), 3 pp.

A modified Zircaloy-2 ingot melted by the nonconsumable electrode melting technique was tested for hardness, composition, mechanical properties and corrosion. Modified Zircaloy-2 is composed of 0.5% tin, 0.1% iron, 0.1% chromium, 0.05% nickel and sponge zirconium. In general, test results were similar to those for Zircaloy-2.—NSA. 11404

6.3.20

Zirconium: Fabrication Techniques and Alloy Development. C. E. Lacy and J. H. Keeler. General Electric Co. *Mech. Eng.*, **77**, 875-878 (1955) Oct.

The fabrication techniques by which zirconium and its alloys have been made successfully into various product forms are described. The neutron-absorption characteristics, mechanical properties and corrosion resistance of zirconium and some zirconium alloys are discussed. (auth).—NSA. 11426

There Are Effective

Corrosion Inhibitors for

COOLING SYSTEMS...

WRIGHT PENECHROMES, *for Example*

Versatile: *Effective throughout a wide pH range and inhibitor concentration.*

Non-fouling: *Maintain high heat transfer rates at product side temperatures up to 600°F. and higher.*

Labor saving: *May be proportioned directly from the drum. No mixing — no chemical vats.*

Why? *Because the Penechromes have been using the combined effect of zinc chromate and penetrants for many years.*

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(Havana, Cuba: Domenech & Co., S. A., 405 Obrapia)
- Softeners, Filters and other external Treating Equipment
- Nelson Chemical Proportioning Pumps

How to prevent corrosion and contamination with LAMINATES

Use KEL-F PLASTIC laminates for:

LINING

tanks
vessels
reactors
drums
pails
piping
chutes
hoppers
fume hoods
ducts

OF KEL-F® FLUOROCARBON PLASTIC

Here is a method

for building corrosion resistance into both new and existing plant equipment -- at reasonable cost in time as well as money. The method employs a tough, cementable laminate of glass cloth coated with KEL-F Fluorocarbon Plastic. As a lining for tanks, vessels, ducts, hoppers, etc., this laminate makes ordinary equipment resistant to liquids and gases as corrosive as fuming nitric acid, and to temperatures as high as 350°F.

Laminates of KEL-F Plastic are manufactured by The Garlock Packing Co. of Palmyra, N.Y. and are available from them for installation by certified applicators. For more information than is contained in these 4 pages, you are invited to communicate directly with The M. W. Kellogg Company, Chemical Manufacturing Division, P. O. Box 469, Jersey City 3, N.J.

SURFACING

laboratory bench tops
floors in chemical plants
rolls
slides
conveyors
resin casting forms
foam rubber molds
skis
reinforced plastic or honeycomb structures

M W KELLOGG

® KEL-F is the registered trademark of THE M. W. KELLOGG COMPANY for its fluorocarbon products.

KEL-F® PLASTIC

With the development of LAMINATES of KEL-F plastic, all kinds of surfaces and equipment can be given the outstanding protection of this unique fluorocarbon plastic. Consisting of a thin layer of KEL-F plastic with a glass cloth backing (for greater adhesion), the laminate can be readily installed over a variety of contours to provide corrosion resistant, anti-adhesive linings and surfacing.

KEL-F PLASTIC laminate provides a practical method of protecting existing plant equipment that cannot—because of design or construction—utilize molded plastic or baked-on coatings. HEAT-SENSITIVE MATERIALS such as aluminum and wood, POROUS SURFACES such as concrete and cast iron, and LARGE, FIXED TANKS AND VESSELS can be made corrosion resistant by a continuous layer of KEL-F PLASTIC laminate—heat-sealed at the seams with the efficient new thermal pulse technique.

KEL-F PLASTIC laminate can prolong the life of your plant equipment . . . reduce shut-down time . . . increase your production. An examination of some of its properties may suggest a place for the laminate in your work.

PROPERTIES

Properties inherent in the new KEL-F fluorocarbon PLASTIC laminate include:

- extreme resistance to chemical action of acids, alkalies, oxidants and solvents
- zero-moisture absorption
- heat resistance approaching 350°F.
- low temperature flexibility
- high abrasion resistance and tensile strength
- low cold flow
- high impact resistance
- high dielectric strength and electrical resistivity
- non-sticking, non-toxic surface characteristics

These outstanding properties make the laminate form of KEL-F plastic a superior material for corrosion control, prevention of product contamination, and for anti-sticking and electrical applications.

STRUCTURE OF KEL-F PLASTIC LAMINATE

The laminate consists of a thin, continuous layer of KEL-F plastic on glass cloth. The plastic extends far enough into the glass structure to provide a strong mechanical bond between plastic and fabric. Enough of the glass cloth remains exposed on the reverse side of the laminate to provide a gripping surface for conventional adhesives. Standard weight laminate is 23-26 mils thick, including an effective plastic coating of 10-12 mils thickness. Both woven and non-woven glass fabrics are satisfactory for laminates. The most common glass cloth in current use is a moderately tight, seven harness satin weave (#181) chrome complex or silane treated.

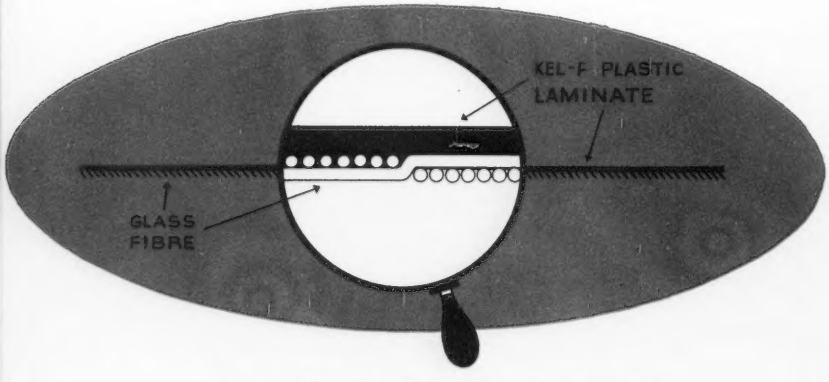


Fig. 1 KEL-F PLASTIC laminate—schematic view.

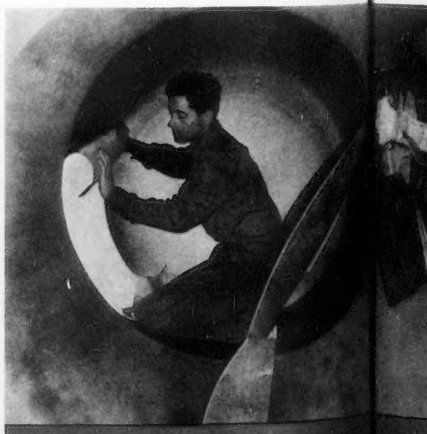


Fig. 2 Installing KEL-F PLASTIC lamin... on tank truck interior. Wood ... plates hold laminate tightly ... while adhesive sets.

INSTALLING KEL-F PLASTIC LAMINATES

(Detailed instructions for installation are presented in *KEL-F PLASTIC laminate, Application Manual*, available on request from M. W. Kellogg.)

Kellogg has devised a number of practical methods for installing KEL-F PLASTIC laminates in tanks, vessels, containers and pipes that can be followed by shop personnel under capable supervision. The basic steps involved are:

1. Cleaning and roughening the surface to which laminate is to be cemented.
2. Cutting and fitting laminate.
3. Applying adhesive to laminate and supporting surface.
4. Holding laminate tightly in place while adhesive sets.
5. Sealing the seams between adjacent sheets of laminate.
6. Testing electrically for pinholes, incomplete seams.

COMPOUND CURVATURES. Almost any contour—from the simple planes of rectangular plating tanks to compound curves of reactors involving flanged pipe connections and dished pressure heads—can be covered with KEL-F PLASTIC laminate. Because of the remarkable thermoplasticity and extensibility of KEL-F plastic, the laminate can be drawn and stretched over these surfaces by hot- and cold-forming techniques.

SEAMING THE LAMINATE

To provide a continuous, corrosion-resistant lining, it is necessary that the joints between adjacent sheets of laminate be sealed with material as durable as the laminate itself. This is accomplished by heat sealing KEL-F PLASTIC tape over the butt joint.

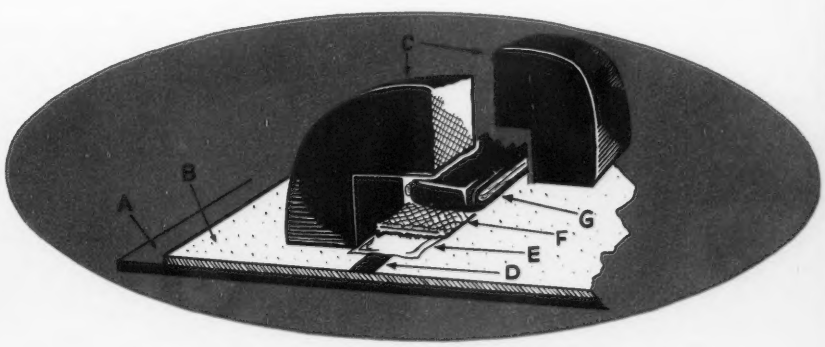
THERMAL PULSE SEALING. A new method of seaming has been developed which greatly reduces seaming time, cuts labor costs and makes tighter seams. Called thermal pulse sealing, this technique depends on a controlled, short-time flow of electrical current through a resistance element, which is held in close contact with the plastic layers. Because the heating element is so light in weight and the current flows for such a brief interval, the tool itself does not remain hot after the current is shut off. Thus the fused joint is automatically quenched.

This new technique is also useful in joining laminate lining to a dispersion coating and for patching dispersion coatings.

MATERIAL SUPPLIERS

Although The M. W. Kellogg Company has developed KEL-F PLASTIC laminates and has applied for patents covering their manufacture, installation and use, arrangements have been made for supply and manufacture of laminates, adhesives, sealing tape, tools, and other materials by companies other than Kellogg. A list of suppliers is available from Kellogg on request.

Fig. 3 Seaming the KEL-F PLASTIC laminate with the new thermal pulse technique using vacuum bag to apply pressure uniformly.



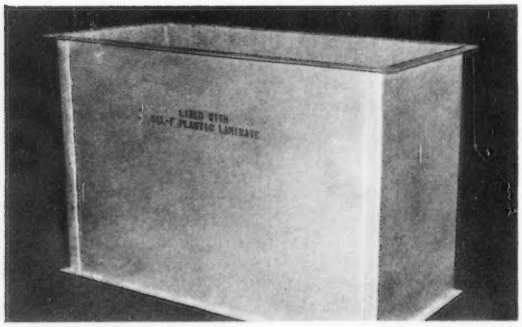
a) Substrate
b) KEL-F PLASTIC laminate
c) Magnets or other means of clamping elements tightly
d) KEL-F PLASTIC tape
e) Aluminum Foil
f) Flexible Heating Strip
g) Non-conductive Flexible Cushion

Fig. 4 Cross section of seaming operation.

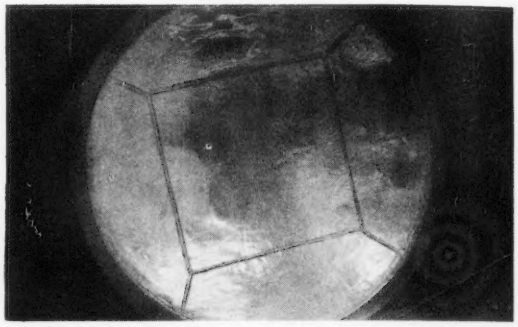
while adhesive sets.

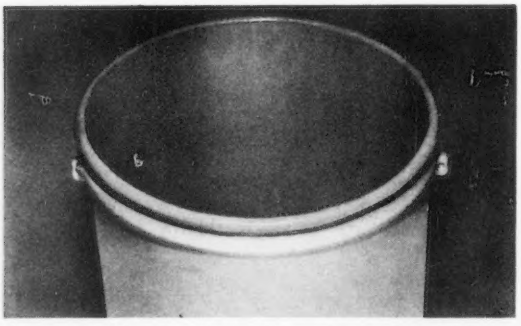
THESE SUCCESSFUL APPLICATIONS

of KEL-F PLASTIC laminates in the chemical industry suggest solutions for many other manufacturing and production problems.

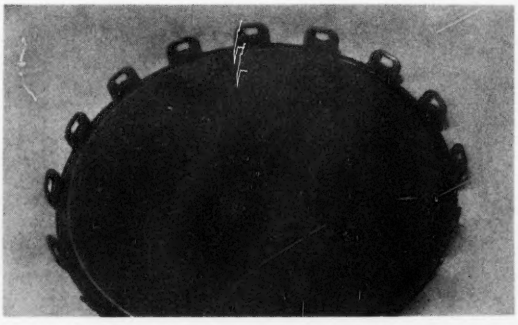


MANY COMPLEX SHAPES—from the simple rectangular plating tank (above) to the compound curves of the dished head of a tank trailer (right) can be protected with KEL-F PLASTIC laminate. Seaming the butt joints is quickly done with the new thermal pulse technique, which greatly reduces seaming time.

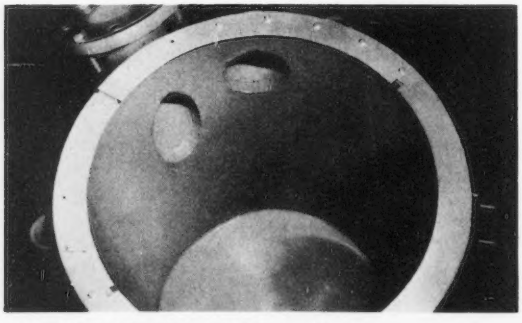




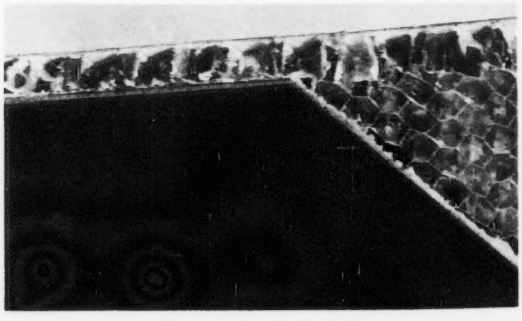
MULTI-PURPOSE pail lined with KEL-F PLASTIC laminate can handle a variety of corrosive chemicals. Its non-toxic, anti-adhesive lining is easily cleaned.



THERMOPLASTICITY and extensibility of KEL-F plastic permits hot- and cold-forming of the laminates over this five gallon pail cover and other compound curvatures.



EXCELLENT ABRASION RESISTANCE of laminate is demonstrated by acid quench tank lining that must withstand impact of rapidly agitated chunks of ice.



LIGHTWEIGHT HONEYCOMB STRUCTURES, (above), conveyors and laboratory bench tops are given a non-corrosive surface with KEL-F PLASTIC laminate.

KELLOGG

THE M. W. KELLOGG COMPANY

Subsidiary of Pullman Incorporated

Chemical Manufacturing Division • P. O. Box 469, Jersey City 3, N. J.

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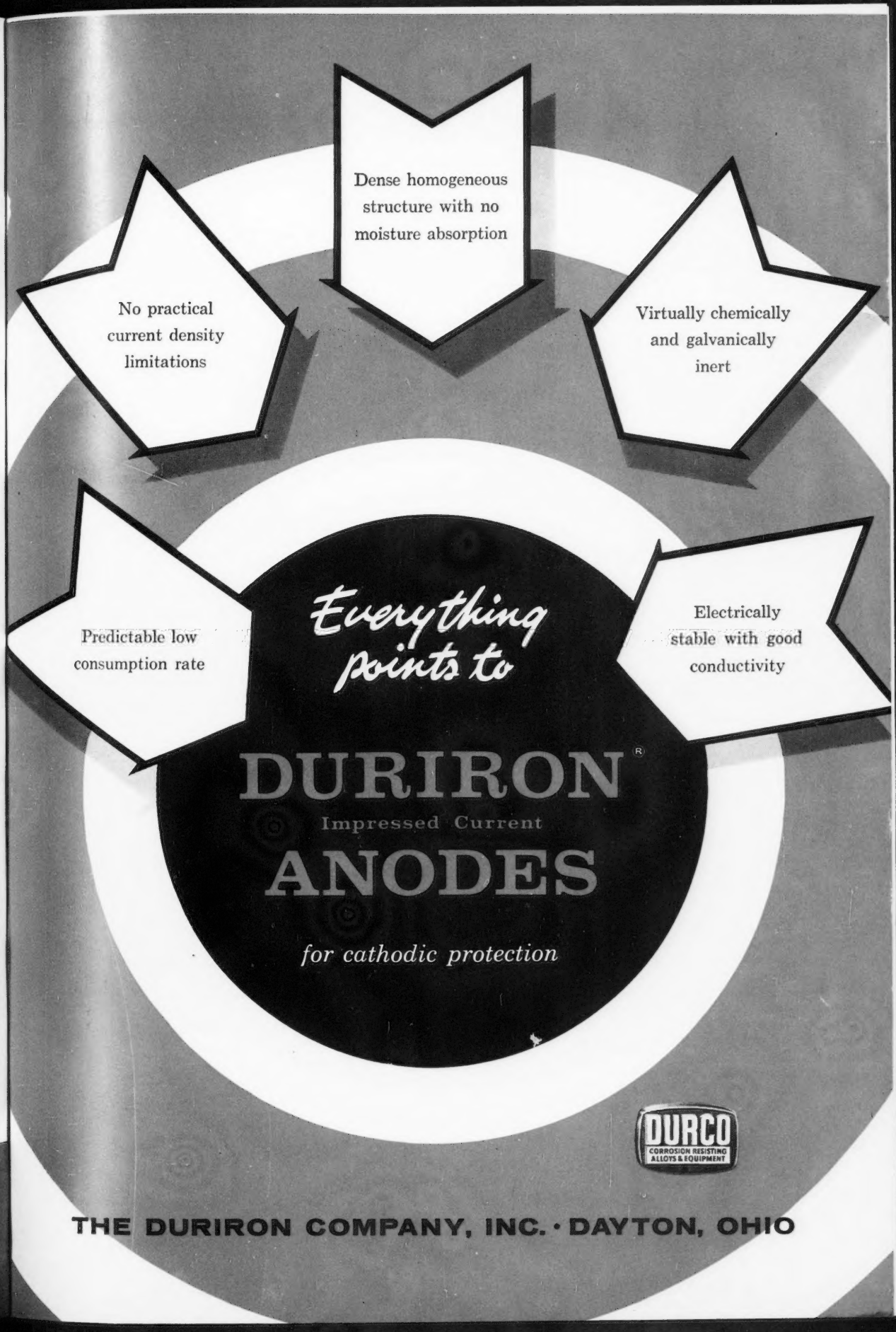
Dense homogeneous structure with no moisture absorption
No practical current density limitations
Virtually chemically and galvanically inert
Predictable low consumption rate
Electrically stable with good conductivity
Everything points to
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Impressed Current
ANODES
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CORROSION RESISTING ALLOYS & EQUIPMENT
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HERE'S 23 YEARS OF PROOF THAT COAL TAR COATINGS LAST LONGER!

THIS coal tar-protected pipeline was buried 23 years in soil permeated with salt water and industrial refuse. But when it was unearthed for inspection, the coating showed no signs of deterioration or failure of any kind!

Isn't that the kind of *proven* protection *you* want? It's the kind of protection you *get* when you specify *Pitt Chem* Coal Tar Pipeline Coatings. For these coatings have demonstrated their tremendous ability to resist soil stress and water absorption—the two principal reasons why "economy" coatings eventually fail.

When you buy *Pitt Chem,* you buy assured pipeline protection with every drum, because *Pitt Chem* Coal Tar Coatings are manufactured to published specifications. ● Call on a *Pitt Chem* man to help you plan your next pipeline protection job. He's fully equipped to give you valuable technical assistance . . . and to guide you to long-run protection economies.

PITT CHEM® TAR BASE COATINGS

- Standard Grade • Modified Grade
- Plasticized Grade • Hotline
- Cold Applied Tar Base Coatings

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Grant Building • Pittsburgh 19, Pa.

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